Robert Miner Dynamic Testing, Inc.

Dynamic Measurements and Analyses for Deep Foundations

January 10, 2022

Ilima Alexander
Flatiron-Lane JV
1400 Talbot Rd S. Ste. 500
Renton, WA 98055

Re: Dynamic Measurements and Analyses of Pile Driving
Bridge 25E (May Creek) Northbound, Pier 2
Initial Drive: December 22, 2021, 11-Day Restrike of Test Pile: January 3, 2022
Secondary Drive of Test Pile: January 6, 2022
PP30"x0.625", APE D50-52 Impact Hammer
I-405 Renton to Bellevue, Renton, Washington RMDT Job No. 21F17

Ms. Alexander,

This transmittal presents results from field measurements and analyses for a Test Pile and one additional production pile in Pier 2 of Northbound Bridge 25E. This work was completed by Robert Miner Dynamic Testing, Inc. (RMDT) at your request.

TEST DETAILS

Pile: The piles are vertical 30" OD open-ended steel pipe piles with a wall thickness of 0.625". We understand that all steel pile material conforms to ASTM A252 Gr 3 specification with a modified minimum yield strength, Fy, of 50 ksi.

Soils and Foundation Design: Subsurface conditions at the site are reported to consist of 20 to 30 ft of recently deposited loose to medium dense primarily granular material underlain by glacially overridden dense to very dense sands and gravels. The foundation design anticipates all piles will achieve end bearing in the glacially overridden soil.

Certain pile design details taken from project documents appear in Table 1. Test Piles in Pier 1 and 2 are required to achieve a nominal driving resistance of 827 and 792 kips, respectively. For further information on the soils and foundation design please refer to appropriate project documents.

FLATIRON | LANE
For Construction
1/20/2022

I-405, Renton to Bellevue Widening & and Express Toll Lanes Project

DOCUMENT REVIEW
☒ APPROVED, NO EXCEPTION TAKEN
☐ APPROVED AS NOTED
☐ RESUBMIT, REVISE AS NOTED

REVIEWED BY: Bon Lien DATE: 01/10/2022

Review is for general conformance with contract or design documents. Sole responsibility for correctness of dimensions, details, quantities, materials, and safety during fabrication and erection shall remain with the contractor.

Table 1: Selected Details for PP30"x0.625" Northbound Pier Piles

Pier	Tip Elevation, ft		Bottom of Pile Cap Elevation (ft)	Estimated Pile Tip Depth (ft)	Minimum Bearing Capacity (kips)	Required Driving Resistance[1] (kips)
	Minimum	Estimated				
1	26.0	15.0	62.0	47.0	761	827
2	20.0	10.5	55.5	45.0	724	792

Note[1]: Required nominal driving resistance for Test Piles.

Hammer: The impact hammer in use during dynamic monitoring was reported to be an APE D50-52 having details as summarized in Table 2.

Table 2: Select Driving System Details Delete one hammer					
Hammer	Maximum Rated Energy kip-ft	Ram Weight kips	Maximum Ram Stroke ft	Helmet Weight kips	Hammer Cushion Stiffness kip/inch
APE D50-52	124	11.0	11.3	5.47	39,981

Methods: We collected high strain dynamic measurements with a Pile Driving Analyzer (PDA) system manufactured by Pile Dynamics, Inc. Sensors mounted on the pile near the pile top measured pile axial strain and acceleration. The PDA unit processed and recorded the measurements. After the field testing the results of individual hammer blows were correlated with depth using penetration resistance data (Pile Driving Log) provided by other participants. We completed CAPWAP signal matching analysis for purposes of evaluating the soil resistance to axial compressive (downward) pile loads. Proposed driving criteria were computed considering the results of wave equation analyses which we completed using program input refined by PDA measurements and CAPWAP analyses. Appendix A contains further information about our equipment and methods.

Test Sequence: Pile 25E-2E was designated as the Test Pile. Prior to RMDT's arrival on site this Test Pile was initially installed with a vibratory hammer. Impact driving with dynamic measurements occurred on December 22, 2021 as the Test Pile advanced from 32 to 53 ft below the surface of the adjacent soil. We also monitored Pile 25E-2C during impact driving from 26 to 51 ft depth; such monitoring was in satisfaction of Standard Specification 6-05.3(9)C.

On January 3, 2022, approximately 11 days after the end of initial impact driving, RMDT monitored a restrike of Pile 25E-2E. During restrike, the Test Pile advanced approximately 16 inches. After that restrike the Test Pile was spliced to increase the length by approximately 60 ft. On January 6, 2022, RMDT returned to the site and monitored the Test Pile as it was impact driven from 54 ft depth to 61 ft depth relative to the surface of the adjacent soil.

During all impact driving a representative of Wood Environmental and Infrastructure Solutions, Inc. (Wood) observed the penetration resistance and maintained a Field Pile Driving Record. For further information regarding the piles, such as tip elevation, layout, or construction activity please refer to the pile driving logs prepared by other project participants.

An RMDT report dated December 23, 2021 presented results for initial driving on the Test Pile and one other production pile as measured on December 22. This report includes results from all RMDT testing completed to date in Pier 2 and thus replaces that prior report which covered only initial impact driving on December 22, 2021.

MEASUREMENT and ANALYSIS RESULTS

Case Method Field Results

Field Case Method results obtained from dynamic measurements of impact pile installation of the Test Pile on December 22, January 3 and 6 are summarized in Table 3. Appendix B contains Case Method results for depth intervals other than the intervals given in Table 3. The Test Pile results in Table 3 and Appendix B include the approximate ram stroke height, STK, the peak measured axial driving stress, CSX, and energy transferred from the hammer to the pile, EMX, with such values as averages for each 1 ft interval of monitored driving. Penetration resistance data in these summaries and other parts of the report are based on values provided by Wood.

Case Method CSX axial driving stress values pertain to the location of our sensors near the pile top and are based on averaging measurements from two strain sensors on opposite sides of the pile. Our PDA sensors were mounted 5 ft below the pile top. The CSI driving stress values in Appendix B and F are obtained from the single sensor with the larger stress. The primary cause of any difference between CSX and CSI is usually considered to be uneven loading at the pile top, or bending.

The PDA measurements allow for an assessment of pile integrity. Pile damage, such as buckling, which causes a substantial reduction of the axial pile stiffness will cause a tension reflection which should be observable in the PDA measurements. We did not observe any sustained evidence of pile damage below our sensors during monitoring.

Table 3. Summary of Case Method Results

Pile	Test Type [1]	Approx. Depth in Soil [2] (ft)	Penetration Resistance (blow/set)	Average Stroke Height "STK" (ft)	Average Transfer Energy "EMX" (kip-ft)	Avg. Max. Compressive. Stress "CSX" (ksi)
25E-2E	EOD	53	29/ft	8.7	55	31
25E-2E	Restrike[3]	54	43/ft	8.8	51	30
25E-2E	EOD	61	49/ft	9.1	57	29

(1) EOD=End of Driving, BOR= Beginning of Restrike and EOR= End of Restrike
(2) Based on the information taken from the field Pile Driving Record or other observation.
(3) These results for restrike of Pile 25E-2E are for the first 12 inches of restrike with ending depth of 54 ft.

CAPWAP Analyses of Soil Resistance

After the field testing RMDT completed CAPWAP analyses using measurements from near the end of initial drive, the start of restrike, and end of final drive on the Test Pile. Table 4 summarizes the CAPWAP results. Detailed CAPWAP results, including the computed friction distributions appear in Appendix C.

For CAPWAP analysis of installation driving on December 22 we selected Blow No. 605 which occurred near the end of driving at a 53 ft depth. CAPWAP analysis of Blow No. 605 yielded an ultimate resistance of 690 kips derived from 380 kips of friction and 310 kips of end bearing.

CAPWAP analysis near the beginning of restrike for Pile 25E-2E (Blow No. 4) yielded an ultimate resistance of 830 kips derived from 520 and 310 kips of shaft resistance and end bearing, respectively. Comparison of the CAPWAP results for initial installation and restrike eleven days later suggest that shaft friction increased by approximately 140 kips during the time between initial drive and restrike.

For CAPWAP analysis of final driving on January 6 we selected Blow No. 315 which occurred near the end of driving at 61 ft depth. CAPWAP analysis of Blow No. 315 yielded an ultimate resistance of 880 kips derived from 390 kips of friction and 490 kips of end bearing.

Table 4. Summary of CAPWAP Results

Pile	Test Type [1]	Test Date	Approx. Depth [2] in Soil (ft)	Penetration Resistance (blow/set)	Computed Ultimate Soil Resistance, (kips)		
					Total	Shaft	Toe
25E-2E	EOD	22Dec2021	53	29/ft	690	380	310
25E-2E	BOR	03Jan2022	53	43/ft	830	520	310
25E-2E	EOD[3]	06Jan2022	61	49/ft	880	390	490

(1) EOD=End of Driving, BOR= Beginning of Restrike and EOR= End of Restrike.
(2) Based on the information taken from the field Pile Driving Record or other observation.
(3) Pile 25E-2E advanced approximately 7 ft under continuous driving from near 54 ft to 61 ft depth; we consider that final driving from 60 to 61 ft is consistent with conditions pertaining to continuous driving, not restrike.

ACCEPTANCE CRITERIA for PRODUCTION PILE DRIVING

At your request this report includes recommended penetration resistance criterion for production piles. We understand that such criterion is to be reviewed and approved by other project participants. The criterion we recommend herein addresses axial resistance on single piles and thus must be applied in conjunction with consideration of other aspects of project specifications and the foundation design which together comprise the acceptance criteria.

To prepare a penetration resistance criterion we used the results from the Test Pile to refine input parameter values for wave equation analysis so as to obtain a reasonably close match between PDA/CAPWAP results, field observations of penetration resistance, and the results of the refined wave equation analysis. The results of this analysis appear in Appendix D as a GRLWEAP Bearing Graph. For an ultimate resistance of 690 kips, an 8.7 ft stroke, and 55 kip-ft of transfer energy the computed penetration resistance is 29 blows per ft (BPF). This result is in good agreement with the field results for the end of driving on the Test Pile for which the CAPWAP computed resistance was 690 kips. The results of this model also agree well with the January 6 results for the end of driving at 61 ft depth if the resistance distribution is adjusted to reflect the larger portion of end bearing at 61 ft depth. For purposes of computing a production acceptance criterion we applied the refined wave equation model to an Inspector's Chart format analysis.

The Inspector's Chart format provides computed penetration resistances for various ram stroke heights and a single fixed total resistance. The proposes Inspector's Chart is for resistance of 682 kips at the end of continuous driving. A target end of drive resistance of 682 kips considers that a 682 kip driving resistance augmented by 110 kips of soil setup following driving will yield an ultimate resistance of 792 kips after approximately 11 days. The applied 110 kip setup value is 0.79 times the 140 kip resistance change apparent from comparison of CAPWAP analyses for drive and restrike at 53 ft depth. Implementation of the 682 kip GRLWEAP analysis would require production pile achieve a penetration resistance value 33 or 29 blows per ft during final continuous driving while the APE D50-52 operates at an 8.1 or 9.0 ft stroke, respectively.

The Inspector's Chart analysis is in Appendix E and immediately after our signature page. Penetration resistances for various ram strokes may be interpolated from tabulated numeric results, or taken from the plot of those results. Combinations of observed ram stroke height and penetration resistance which plot above and to the right side of the Inspector's Chart may be taken as meeting or exceeding the acceptance criteria we recommend herein for an an ultimate resistance 792 kips in Pier 2.

For routine driving we recommend that the ram stroke be limited to approximately 9.3 ft. This limitation is intended to reduce the potential for pile damage due to driving stress. We also recommend proper axial alignment of the hammer, helmet and pile at all times. Our analysis addresses net axial stresses and does not account for local stresses that might be caused by uneven impact at the pile top, bending, or obstructions which cause concentrated stresses at the pile tip or lateral strain.

The following limitations or qualifications apply to use of the provided Inspector's Charts:

1) The Inspector's Chart is for circumstance similar to those prevailing when the Test Pile was driven. For example, our analysis reflects observed hammer performance; if there is reason for uncertainty about consistent hammer performance then qualified review is recommended. Also, our Inspector's Chart results should be applied to observations during continuous driving and should not be applied if the pile has not been driven continuously for at least 3 ft, with the last ft of such driving used for evaluation of penetration resistance.

2) When using the Inspectors Chart for an ending resistance of 682 kips the pile penetration below the soil line must be at least 53 ft. This penetration requirement reflects consideration that the restrike at 53 ft depth yielded 140 kips of setup; a target resistance of 682 kips at final drive and 110 kips of time-dependent soil setup will yield the required 792 kip long term resistance.

3) Additional requirements imposed by the specifications or foundation design are applicable and should be part of the overall acceptance criteria. Such added requirements may include minimum penetration, minimum tip elevation, pile position and orientation and aspects not directly related to soil resistance. The stroke and penetration resistance criterion given in our Inspectors Chart Analysis addresses attainment of soil resistance to axial compressive (downward) pile loads at Pier 2.

4) The proposed acceptance criterion requires that the ram stroke height be observed, recorded and applied to acceptance decisions. In most cases the ram stroke height may be effectively monitored using a Saximeter® manufactured by Pile Dynamics, Inc.

5) Pile acceptance and the Pile Driving Log should be evaluated by an engineer with experience and competence for that task.

RESULTS for Pile 25E-2C

Flatiron Lane requested RMDT to monitor Pile 25E-2C for purposes of compliance with Standard Specification 6-05.3(9)C. Part of this specification pertains to use of leads which are not considered to be fixed at top and bottom. Appendix F contains results and discussion pertaining our PDA measurements relative to that specification.

ADDITIONAL CONSIDERATIONS

The static soil resistance values computed with the Case Method and from CAPWAP are estimates of the mobilized, axial compressive soil resistance at the time of testing. These soil resistance results are ultimate resistance values and they must be reduced by an appropriate factor of safety or resistance factor to obtain working loads or factored resistances.

During pile driving, excess positive pore pressures are often generated. These pore pressures reduce the effective stress acting on the pile thereby reducing the soil resistance to pile penetration, and the pile capacity at the time of driving. As these pore pressures dissipate, the soil strength increases and the soil resistance increases. This phenomena is often called soil setup or “soil freeze”. Alternately, relaxation of end bearing may occur for piles driven into dense granular soils or rock. Dynamic testing during restrike with adequate set per blow usually yields a better indication of long term soil resistance than a test at the end of pile driving.

Numerous factors are usually considered in pile foundation design. Some of these considerations include cyclic loading performance, lateral and uplift loading requirements, effective stress changes (due to changes in water table, excavations, fills or other changes in overburden pressure), settlement from underlying weaker layers, the effects of scour or liquefaction on pile capacity, as well as pile group effects, strong ground motion, and time dependant or temperature dependent changes to the strength of the pile or soil . These factors have not been evaluated by RMDT in the interpretation of the dynamic testing results. The foundation designer should determine if these considerations are applicable to this project and, if so, their impact on the foundation design

It was a pleasure to If you or others have any questions regarding our field work or these analyses please do not hesitate to contact us.

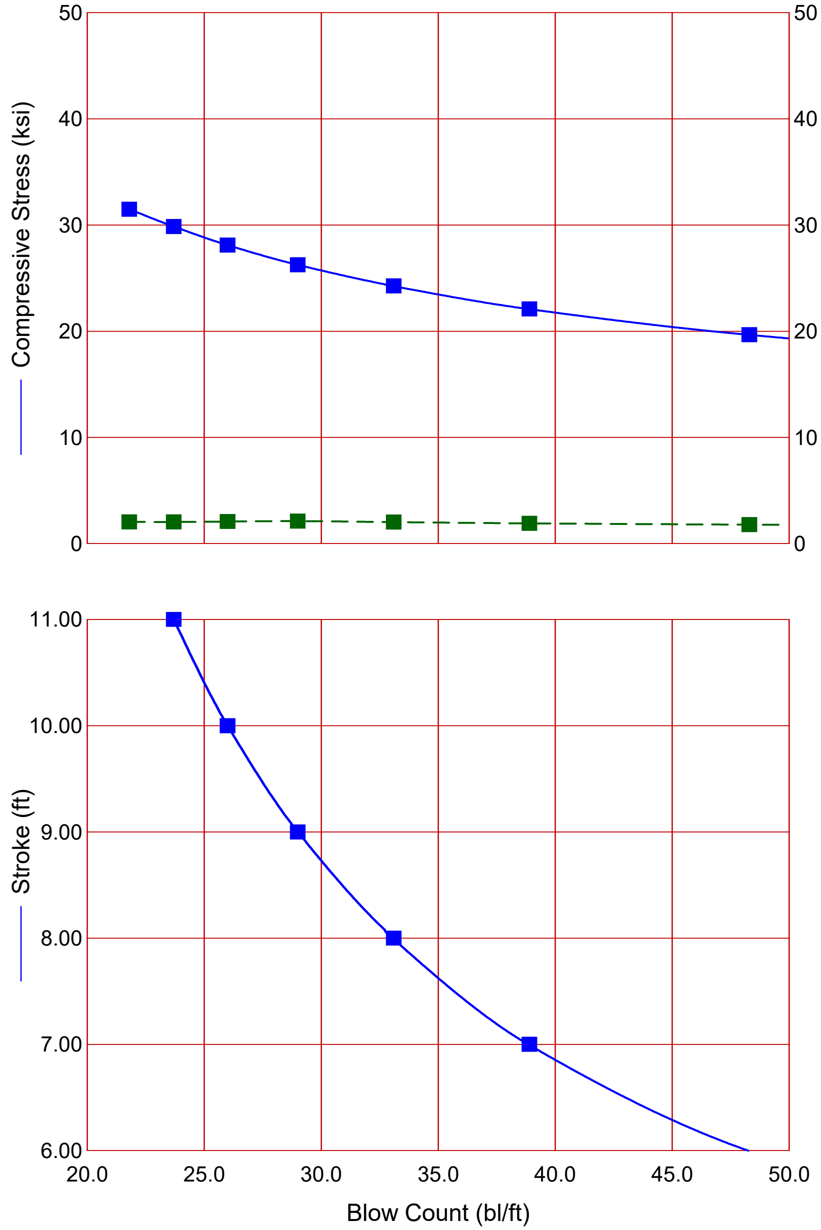
Sincerely,

Robert F. Miner, P.E. January 10, 2022

Robert Miner Dynamic Testing, Inc.

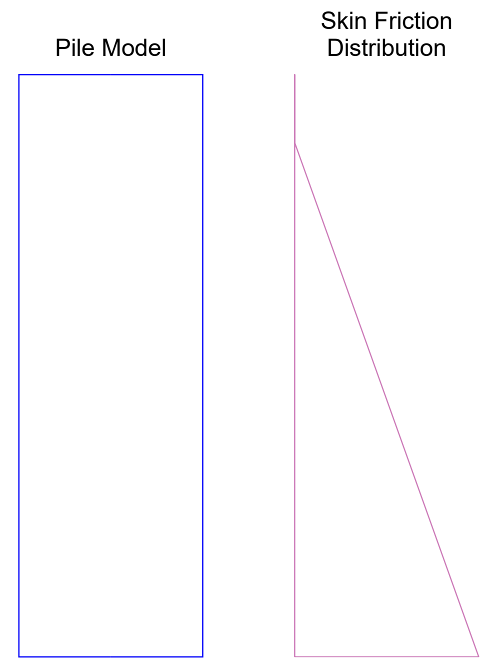
Robert Miner Dynamic Testing, Inc.
FLJV, Br25E Pier 2, D50-52 IC @682k EOD

10-Jan-2022
GRLWEAP Version 2010



APE D 50-52

Capacity	682.0	kips
Ram Weight	11.03	kips
Efficiency	0.720	
Pressure	1717 (108%)	psi
Helmet Weight	5.40	kips
Hammer Cushion	40000	kips/in
COR of H.C.	0.800	
Skin Quake	0.100	in
Toe Quake	0.350	in
Skin Damping	0.080	s/ft
Toe Damping	0.090	s/ft
Pile Length	60.00	ft
Pile Penetration	53.00	ft
Pile Top Area	57.67	in2



Res. Shaft = 55 %
(Proportional)

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count bl/ft	Stroke ft	Energy kips-ft
682.0	10.61	1.23	306.2	3.00	13.73
682.0	13.65	1.52	98.3	4.00	21.98
682.0	16.91	1.59	64.3	5.00	29.45
682.0	19.67	1.79	48.3	6.00	36.65
682.0	22.09	1.92	38.9	7.00	43.49
682.0	24.26	2.04	33.1	8.00	50.12
682.0	26.25	2.13	29.0	9.00	56.61
682.0	28.11	2.09	26.0	10.00	62.91
682.0	29.86	2.05	23.7	11.00	69.22
682.0	31.48	2.05	21.8	12.00	75.37

APPENDIX A
AN INTRODUCTION INTO DYNAMIC PILE TESTING METHODS

BACKGROUND

Modern procedures of design and construction control require verification of bearing capacity and integrity of deep foundations during preconstruction test programs and also production installation. Dynamic pile testing methods meet this need economically and reliably, and therefore, form an important part of a quality assurance program when deep foundations are executed. Several dynamic pile testing methods exist; they have different benefits and limitations and different requirements for proper execution.

The Case Method of dynamic pile testing, named after the Case Institute of Technology where it was developed between 1964 and 1975, requires that a substantial ram mass (such as that of a pile driving hammer) impacts the pile top such that the pile undergoes at least a small permanent set. The method is therefore also referred to as a “High Strain Method”. The Case Method requires dynamic measurements on the pile or shaft under the ram impact and then an evaluation of various quantities based on closed form solutions of the wave equation, a partial differential equation describing the motion of a rod under the effect of an impact. Conveniently, measurements and analyses are done by a single piece of equipment: the Pile Driving Analyzer® (PDA). However, for bearing capacity evaluations an important additional method is CAPWAP® which performs a much more rigorous analysis of the dynamic records than the simpler Case Method.

A related analysis method is the “Wave Equation Analysis” which calculates a relationship between bearing capacity and pile stress and field blow count. The GRLWEAP™ program performs this analysis and provides a complete set of helpful information and input data.

The following description deals primarily with the Case Method or “High Strain Test” Method of pile testing, however, for the sake of completeness, the “Low Strain Test” performed with the Pile Integrity Test™ (PIT), mainly for pile integrity evaluation, will also be described.

RESULTS FROM DYNAMIC TESTING

There are two main objectives of high strain dynamic pile testing:

- *Dynamic Pile Monitoring* and
- *Dynamic Load Testing*.

Dynamic pile monitoring is conducted during the installation of impact driven piles to achieve a safe and economical pile installation. Dynamic load testing, on the other hand, has as its primary goal the assessment of pile bearing capacity. It is applicable to both cast *insitu* piles or drilled shafts and impact driven piles during restrike.

Dynamic Pile Monitoring

During pile installation, the sensors attached to the pile measure pile top force and velocity. A PDA conditions and processes these signals and calculates or evaluates:

- Bearing capacity at the time of testing, including an assessment of shaft resistance development and driving resistance. This information supports formulation of a driving criterion.

- Dynamic pile stresses, axial and averaged over the pile cross section, both tensile and compressive, during pile driving to limit the potential of damage either near the pile top or along its length. Bending stresses can be evaluated at the point of sensor attachment.

- Pile integrity assessment by the PDA is based on the recognition of certain wave reflections from along the pile. If detected early enough, a pile may be saved from complete destruction. On the other hand, once damage is recognized measures can be taken to prevent reoccurrence.

- Hammer performance parameters including the energy transferred to the pile, the hammer speed in blows per minute and the stroke of open ended diesel hammers.

Dynamic Pile Load Testing

Bearing capacity testing of either driven piles or drilled shafts applies the same basic measurement approach of dynamic pile monitoring. However, the test is done independent of the pile installation process and therefore a pile driving hammer or other dynamic loading device may not be available. If a special ram has to be mobilized then its weight should be between 0.8 and 2% of the test load (e.g. between 4 and 10 tons for a 500 ton test load) to assure sufficient soil resistance activation.

For a successful test, it most important that the test is conducted after a sufficient waiting time following pile installation for soil properties approaching their long term condition or concrete to properly set. During testing, PDA results of pile/shaft stresses and transferred energy are used to maintain safe stresses and assure sufficient resistance activation. For safe and sufficient testing of drilled shafts, ram energies are often increased from blow to blow until the test capacity has been activated. On the other hand, restrike tests on driven piles may require a warm hammer so that the very first blow produces a complete resistance activation. Data must be evaluated by CAPWAP for bearing capacity.

After the dynamic load test has been conducted with sufficient energy and safe stresses, the CAPWAP analysis provides the following results:

- Bearing capacity i.e. the mobilized capacity present at the time of testing

- Resistance distribution including shaft resistance and end bearing components

- Stresses in pile or shaft calculated for both the static load application and the dynamic test. These stresses are averages over the cross section and do not include bending effects or nonuniform contact stresses, e.g. when the pile toe is on uneven rock.

- Shaft impedance vs depth; this is an estimate of the shaft shape if it differs substantially from the planned profile

- Dynamic soil parameters for shaft and toe, i.e. damping factors and quakes (related to the dynamic stiffness of the resistance at the pile/soil interface.)

MEASUREMENTS

PDA

The basis for the results calculated by the PDA are pile top strain and acceleration measurements which are converted to force and velocity records, respectively. The PDA conditions, calibrates and displays these signals and immediately computes average pile force and velocity thereby eliminating bending effects. Using closed form Case Method solutions, based on the one-dimensional linear wave equation, the PDA calculates the results described in the analytical solutions section below.

HPA

The ram velocity may be directly obtained using radar technology in the Hammer Performance Analyzer™. For this unit to be applicable, the ram must be visible. The impact velocity results can be automatically processed with a PC or recorded on a strip chart.

Saximeter™

For open end diesel hammers, the time between two impacts indicates the magnitude of the ram fall height or stroke. This information is not only measured and calculated by the PDA but also by the convenient, hand-held Saximeter.

PIT

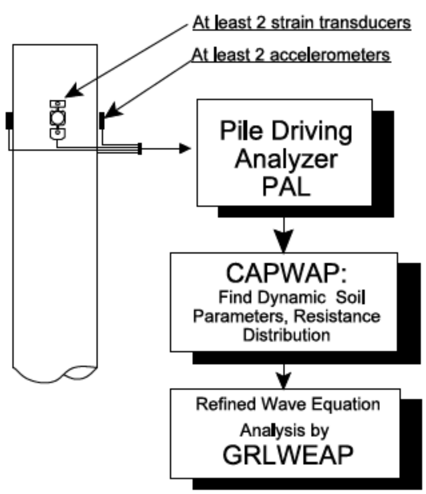
The Pile Integrity Tester™ (PIT) can be used to evaluate defects in concrete piles or shafts which may have occurred during driving or casting. Also timber piles of limited length can be tested in that manner. This so-called "Low Strain Method" or “Pulse-Echo Method” of integrity testing requires only the measurement of acceleration at the pile top. The stress wave producing impact is then generated by a small hand-held hammer and the records interpreted in the time domain. PIT also supports the so-called “Transient Response Method” which requires the additional measurement of the hammer force and an analysis in the frequency domain. This method may also be used to evaluate the unknown length of deep foundations under existing structures.

ANALYTICAL SOLUTIONS
BEARING CAPACITY

Wave Equation

GRL has written the GRLWEAP™ program which calculates a relationship between bearing capacity, pile stress and blow count. This relationship is often called the "bearing graph." Once the blow count is known from pile installation logs, the bearing graph yields the bearing capacity. This approach requires no measurements and therefore can be performed during the design stage of a project, for example for the selection of hammer, cushion and pile size.

After dynamic pile monitoring and/or dynamic load testing has been performed, the "Refined Wave Equation Analysis" or RWEA (see schematic below) is often performed by inputting the PDA and CAPWAP calculated parameters. Then the bearing graph from the RWEA is the basis for a safe and sufficient driving criteria.



Case Method

The Case Method is a closed form solution based on a few simplifying assumptions such as ideal plastic soil behavior and an ideally elastic and uniform pile. Given the measured pile top force F(t) and pile top velocity v(t), the total soil resistance is

$$R(t) = \tfrac{1}{2}\{[F(t) + F(t_2)] + Z[v(t) - v(t_2)]\} \qquad (1)$$

where

t = a point in time after impact
t_2 = time $t + 2L/c$
L = pile length below gages
c = $(E/\rho)^{1/2}$ is the speed of the stress wave
ρ = pile mass density
Z = EA/c is the pile impedance
E = elastic modulus of the pile ($\rho\, c^2$)
A = pile cross sectional area

The total soil resistance consists of a dynamic (R_d) and a static (R_s) component. The static component is therefore

$$R_s(t) = R(t) - R_d(t) \qquad (2)$$

The dynamic component may be computed from a soil damping factor, J, and a pile toe velocity, $v_t(t)$ which is conveniently calculated for the pile toe. Using wave considerations, this approach leads immediately to the dynamic resistance

$$R_d(t) = J[F(t) + Zv(t) - R(t)] \qquad (3)$$

and finally to the static resistance by means of Equation 2.

There are a number of ways in which Eq. 1 through 3 can be evaluated. Most commonly, t_2 is set to that time at which the static resistance becomes maximum. The result is the so-called **RMX** capacity. Damping factors for RMX typically range between 0.5 for coarse grained materials to 1.0 for clays. The **RSP** capacity (this method is most commonly referred to in the literature, yet it is not very frequently used) requires damping factors between 0.1 for sand and 1.0 for clay. Another capacity, **RA2**, determines the capacity at a time when the pile is essentially at rest and thus damping is small; RA2 therefore requires no damping parameter. In any event, the proper Case Method and its associated damping parameter is most conveniently found after a CAPWAP analysis has been performed.

The static resistance calculated by Case Method or CAPWAP is the mobilized resistance at the time of testing. Consideration therefore has to be given to soil setup or relaxation effects and whether or not a sufficient set has been achieved under the test loading that would correspond to a full activation of the ultimate soil resistance.

The PDA also calculates an estimate of shaft resistance as the difference between force and velocity times impedance at the time immediately prior to the return of the stress wave from the pile toe. This shaft resistance is not reduced by damping effects and is therefore called the total shaft resistance **SFT**. A correction for damping effects produces the static shaft resistance estimate, **SFR**.

The Case Method solution is simple enough to be evaluated "in real time," i.e. between hammer blows, using the PDA. It is therefore possible to calculate all relevant results for all hammer blows and plot these results as a function of depth or blow number. This is done in the PDAPLOT program.

CAPWAP

The CAse Pile Wave Analysis Program combines the wave equation pile and soil model with the Case Method measurements. Thus, the solution includes not only the total and static bearing capacity values but also the shaft resistance, end bearing, damping factors and soil stiffnesses. The method iteratively calculates a number of unknowns by signal matching. While it is necessary to make hammer performance assumptions for a GRLWEAP analysis, the CAPWAP program works with the pile top measurements. Furthermore, while GRLWEAP and Case Method require certain assumptions regarding the soil behavior, CAPWAP calculates these soil parameters.

STRESSES

During pile monitoring, it is important that compressive stress maxima at pile top and toe and tensile stress maxima somewhere along the pile be calculated for each hammer blow.

At the pile top (location of sensors) both the maximum compression stress, **CSX**, and the maximum stress from individual strain transducers, **CSI**, are directly obtained from the measurements. Note that CSI is greater than or equal to CSX and the difference between CSI and CSX is a measure of bending in the plane of the strain transducers. Note also that all stresses calculated for locations below the sensors are averaged over the pile cross section and therefore do not include components from either bending or eccentric soil resistance effects.

The PDA calculates the compressive stress at the pile bottom, **CSB**, assuming (a) a uniform pile and (b) that the pile toe force is the maximum value of the total resistance R(t) minus the total shaft resistance, SFT. Again, for this stress estimation uniform resistance force are assumed (e.g. not a sloping rock.)

For concrete piles, the maximum tension stress, **TSX**, is also of great importance. It occurs at some point below the pile top. The maximum tension stress can be computed from the pile top measurements by finding the maximum tension wave (either traveling upward, W_U, or downward, W_d) and reducing it by the minimum compressive wave traveling in opposite direction.

$$W_u = ½[F(t) - Zv(t)] \qquad (4)$$

$$W_d = ½[F(t) + Zv(t)] \qquad (5)$$

CAPWAP also calculates tensile and compressive stresses along the pile and, in general, more accurately than the PDA. In fact, for non-uniform piles or piles with joints, cracks or other discontinuities, the closed form solutions from the PDA may be in error.

PILE INTEGRITY

High Strain Tests (PDA)

Stress waves in a pile are reflected wherever the pile impedance, $Z = EA/c = \rho cA = A \sqrt{(E\ \rho)}$, changes. Therefore, the pile impedance is a measure of the quality of the pile material (E, ρ, c) and the size of its cross section (A). The reflected waves arrive at the pile top at a time which is greater the farther away from the pile top the reflection occurs. The magnitude of the change of the upward traveling wave (calculated from the measured force and velocity, Eq. 4) indicates the extent of the cross sectional change. Thus, with β_i (**BTA**) being a relative integrity factor which is unity for no impedance change and zero for the pile end, the following is calculated by the PDA.

$$\beta_i = (1 - \alpha_i)/(1 + \alpha_i) \qquad (6)$$

with

$$\alpha_i = ½(W_{UR} - W_{UD})/(W_{Di} - W_{UR}) \qquad (7)$$

where

W_{UR} is the upward traveling wave at the onset of the reflected wave. It is caused by resistance.

W_{UD} is the upwards traveling wave due to the damage reflection.

W_{Di} is the maximum downward traveling wave due to impact.

It can be shown that this formulation is quite accurate as long as individual reflections from different pile impedance changes have no overlapping effects on the stress wave reflections.

Without rigorous derivation, it has been proposed to consider as slight damage when β is above 0.8 and a serious damage when β is less than 0.6.

Low Strain Tests (PIT)

The pile top is struck with a held hand hammer and the resulting pile top velocity is measured, displayed and interpreted for signs of wave reflections. In general, a comparison of the reflected acceleration leads to a relative measure of extent of damage, again the location of the problem is indicated by the arrival time of the reflection. PIT records can also be interpreted by the β-Method. However, low strain tests do not activate much resistance which simplifies Eq. 7 since W_{UR} is then equal to zero.

For drilled shafts and PIT records that clearly show a toe reflection, an approximate shaft profile can be calculated from low strain records using the PITSTOP program's PROFILE routine.

HAMMER PERFORMANCE

The PDA calculates the energy transferred to the pile top from:

$$E(t) = {}_o\!\int^t F(t)v(t)\,dt \qquad (8a)$$

The maximum of the E(t) curve is the most important information for an overall evaluation of the performance of a hammer and driving system. This **EMX** value allows for a classification of the hammer's performance when presented as the rated transfer efficiency, also called energy transfer ratio (**ETR**) or global efficiency

$$e_T = EMX/E_R \qquad (8b)$$

where

E_R is the manufacturer's rated energy value.

Both Saximeter and PDA calculate the stroke (**STK**) of an open end diesel hammer using

$$STK = (g/8)\,T_B^{\,2} - h_L \qquad (9)$$

where

g is the earth's gravitational acceleration,
T_B is the time between two hammer blows,
h_L is a stroke loss value due to gas compression and time losses during impact (usually 0.3 ft or 0.1 m).

DETERMINATION OF WAVE SPEED

An important facet of dynamic pile testing is an assessment of pile material properties. Since in general force is determined from strain by multiplication with elastic modulus, E, and cross sectional area, A, the dynamic elastic modulus has to be determined for pile materials other than steel. In general, the records measured by the PDA clearly indicate a pile toe reflection as long as pile penetration per blow is greater than 1 mm or .04 inches. The time between the onset of the force and velocity records at impact and the onset of the reflection from the toe (usually apparent by a local maximum of the wave up curve) is the so-called wave travel time, T. Dividing 2L (L is here the length of the pile below sensors) by T leads to the stress wave speed in the pile:

$$c = 2L/T \qquad (10)$$

The elastic modulus of the pile material is related to the wave speed according to the linear elastic wave equation theory by

$$E = c^2 \rho \tag{11}$$

Since the mass density of the pile material, ρ, is usually well known (an exception is timber for which samples should be weighed), the elastic modulus is easily found from the wave speed. Note, however, that this is a dynamic modulus which is generally higher than the static one and that the wave speed depends to some degree on the strain level of the stress wave. For example, experience shows that the wave speed from PIT is roughly 5% higher than the wave speed observed during a high strain test.

Other Notes:

- If the pile material is nonuniform then the wave speed c, according to Eq. 10, is an average wave speed and does not necessarily reflect the pile material properties of the location where the strain sensors are attached to the pile top. For example, pile driving often causes fine tension cracks some distance below the top of concrete piles. Then the average c is slower than that at the pile top. It is therefore recommended to determine E in the beginning of pile driving and not adjust it when the average c changes.

- If the pile has such a high resistance that there is no clear indication of a toe reflection then the wave speed of the pile material must be determined either by assumption or by taking a sample of the concrete and measuring its wave speed in a simple free column test. Another possibility is to use the proportionality relationship, discussed under "DATA QUALITY CHECKS" to find c as the ratio between the measured velocity and measured strain.

DATA QUALITY CHECKS

Quality data is the first and foremost requirement for accurate dynamic testing results. It is therefore important that the measurement engineer performing PDA or PIT tests has the experience necessary to recognize measurement problems and take appropriate corrective action should problems develop. Fortunately, dynamic pile testing allows for certain data quality checks because two independent measurements are taken that have to conform to certain relationships.

Proportionality

As long as there is only a wave traveling in one direction, as is the case during impact when only a downward traveling wave exists in the pile, force and velocity measured at the pile top are proportional

$$F = v\, Z = v\, (EA/c) \tag{12a}$$

This relationship can also be expressed in terms of stress

$$\sigma = v\, (E/c) \tag{12b}$$

or strain

$$\epsilon = v / c \tag{12c}$$

This means that the early portion of strain times wave speed must be equal to the velocity unless the proportionality is affected by high friction near the pile top or by a pile cross sectional change not far below the sensors. Checking the proportionality is an excellent means of assuring meaningful measurements.

Measurements are always taken at opposite sides of the pile as a means of calculating the average force and velocity in the pile. The velocity on the two sides of the pile is very similar even when high bending exists. Thus, an independent check of the velocity measurements is easy and simple.

Strain measurements may differ greatly between the two sides of the pile when bending exists. It is even possible that tension is measured on one side while very high compression exists on the other side of the pile. In extreme cases, bending might be so high that it leads to a nonlinear stress distribution. The averaging of the two strain signals does then not lead to the average pile force and proportionality will not be achieved.

When testing drilled shafts, measurements of strain may also be affected by local concrete quality variations. It is then often necessary to use four strain transducers spaced at 90 degrees around the pile for an improved strain data quality. The use of four transducers is also recommended for large pile diameters, particularly when it is difficult to mount the sensors at least two pile widths or diameters below the pile top.

LIMITATIONS, ADDITIONAL CONSIDERATIONS

Mobilization of capacity

Estimates of pile capacity from dynamic testing indicate the **mobilized pile capacity at the time of testing**. At very high blow counts (low set per blow), dynamic test methods tend to produce lower bound capacity estimates as not all resistance (particularly at and near the toe) is fully activated.

Time dependent soil resistance effects

Static pile capacity from dynamic method calculations provide an estimate of the axial pile capacity. Increases and decreases in the pile capacity with time typically occur (soil setup/relaxation). Therefore, **restrike testing usually yields a better indication of long term pile capacity than a test at the end of pile driving**. Often a wait period of one or two days between end of driving and restrike is satisfactory for a realistic prediction of pile capacity but this waiting time depends, among other factors, on the permeability of the soil.

(A) Soil setup

Because excess positive pore pressures often develop during pile driving in fine grained soil (clays, silts or even fine sands), the capacity of a pile at the time of driving may often be less than the long term pile capacity. These pore pressures reduce the effective stress acting on the pile thereby reducing the soil resistance to pile penetration, and thus the pile capacity at the time of driving. As these pore pressures dissipate, the soil resistance acting on the pile increases as does the axial pile capacity. This phenomena is routinely called soil setup or soil freeze.

(*B) Relaxation*

Relaxation (capacity reduction with time) has been observed for piles driven into weathered shale, and may take several days to fully develop. Pile capacity estimates based upon initial driving or short term restrike tests can significantly overpredict long term pile capacity. Therefore, piles driven into shale should be tested after a minimum one week wait either statically or dynamically (with particular emphasis than on the first few blows). Relaxation has also been observed for displacement piles driven into dense saturated silts or fine sands due to a negative pore pressure effect at the pile toe. Again, restrike tests should be used, with great emphasis on early blows.

Capacity results for open pile profiles

Larger diameter open ended pipe piles (or H-piles which do not bear on rock) may behave differently under dynamic and static loading conditions. Under dynamic loads the soil inside the pile or between its flanges may slip and produce internal friction while under static loads the plug may move with the pile, thereby creating end bearing over the full pile cross section. As a result both friction and end bearing components may be different under static and dynamic conditions.

CAPWAP Analysis Results

A portion of the soil resistance calculated on an individual soil segment in a CAPWAP analysis can usually be shifted up or down the shaft one soil segment without significantly altering the match quality. Therefore, use of the CAPWAP resistance distribution for uplift, downdrag, scour, or other geotechnical considerations should be made with an understanding of these analysis limitations.

Stresses

PDA and CAPWAP calculated stresses are average values over the cross section. Additional allowance has to be made for bending or non-uniform contact stresses. To prevent damage it is therefore important to maintain good hammer-pile alignment and to protect the pile toes using appropriate devices or an increased cross sectional area.

In the United States is has become generally acceptable to limit the dynamic installation stresses of driven piles to the following levels:

- 90% of yield strength for steel piles
- 85% of the concrete compressive strength - after subtraction of the effective prestress - for concrete piles in compression

100% of effective prestress plus ½ of the concrete's tension strength for prestressed piles in tension

70% of the reinforcement strength for regularly reinforced concrete piles in tension

300% of the static design allowable stress for timber

Note that the dynamic stresses may either be directly measured at the pile top by the PDA or calculated by the PDA for other locations along the pile based on the pile top measurements.

Additional design considerations

Numerous factors have to be considered in pile foundation design. Some of these considerations include

- additional pile loading from downdrag or negative skin friction,
- lateral and uplift loading requirements
- effective stress changes (due to changes in water table, excavations, fills or other changes in overburden),
- long term settlements in general and settlement from underlying weaker layers and/or pile group effects,

These factors have not been evaluated by GRL and have not been considered in the interpretation of the dynamic testing results. The foundation designer should determine if these or any other considerations are applicable to this project and the foundation design.

Wave equation analysis results

The results calculated by the wave equation analysis program depend on a variety of hammer, pile and soil input parameters. Although attempts have been made to base the analysis on the best available information, actual field conditions may vary and therefore stresses and blow counts may differ from the predictions reported. Capacity predictions derived from wave equation analyses should use restrike information. However, because of the uncertainties associated with restrike blow counts and restrike hammer energies, correlations of such results with static test capacities with have often displayed considerable scatter.

As for PDA and CAPWAP, the theory on which GRLWEAP is based is the one-dimensional wave equation. For that reason, stress predictions by the wave equation analysis can only be averages over the pile cross section. Thus, bending stresses or stress concentrations due to non-uniform impact or uneven soil or rock resistance are not considered in these results. Stress maxima calculated by the wave equation are usually subjected to the same limits as those measured directly or calculated from measurements by the PDA.

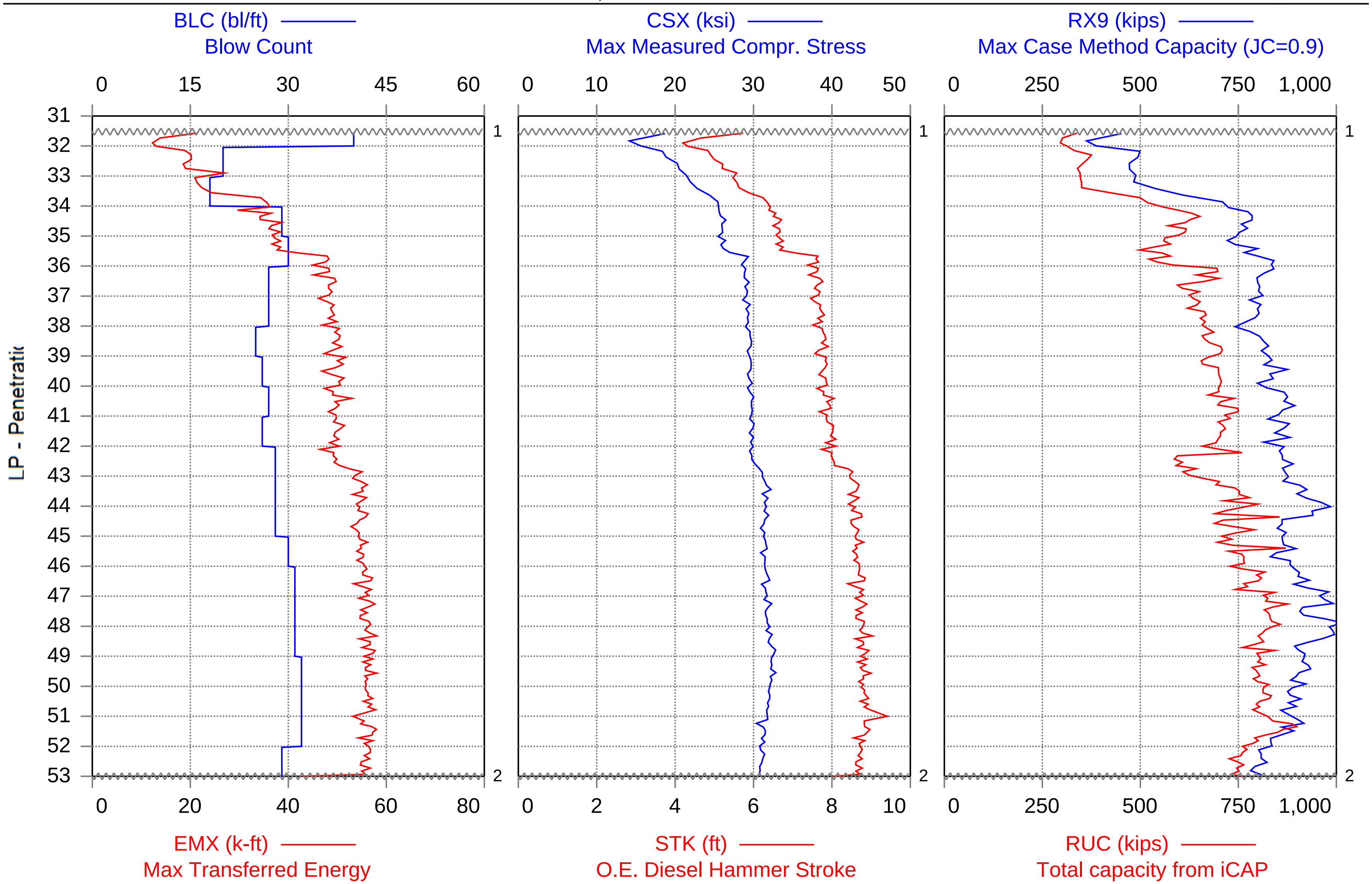
Appendix B

Summary of Case Method Results

Robert Miner Dynamic Testing, Inc. - PDIPLOT2 Ver 2021.1.61.0 - Case Method & iCAP® Results

Printed: 23-December-2021 Test started: 22-December-2021

Flatiron-Lane JV, 25ENB - 25E-2E



1 - Start of test on 12/22/2021 at 10:24 PM

2 - End of test on 12/22/2021 at 10:40 PM

Case Method & iCAP® Results

Flatiron-Lane JV, 25ENB - 25E-2E PP30"x0.625", APE D50-52

OP: RMDT Date: 22-December-2021

AR:	57.68 in²	SP:	0.492 k/ft³
LE:	55.00 ft	EM:	30,000 ksi
WS:	16,807.9 f/s	JC:	0.90

CSI: Max F1 or F2 Compr. Stress
CSX: Max Measured Compr. Stress
STK: O.E. Diesel Hammer Stroke
EMX: Max Transferred Energy
BPM: Blows per Minute
FMX: Maximum Force
VMX: Maximum Velocity
RX9: Max Case Method Capacity (JC=0.9)
RUC: Total capacity from iCAP

BL#	Depth	BLC	TYPE	CSI	CSX	STK	EMX	BPM	FMX	VMX	RX9	RUC
	ft	bl/ft		ksi	ksi	ft	k-ft	bpm	kips	f/s	kips	kips
20	32.0	40	AV11	19.9	16.3	4.78	15.2	53.7	940	8.3	407	312
			STD	3.4	2.2	0.67	4.8	3.4	124	1.2	56	19
			MAX	26.9	20.1	5.92	23.4	57.7	1,160	10.3	515	347
			MIN	16.1	13.2	4.05	10.3	48.2	764	6.9	307	277
40	33.0	20	AV20	22.1	19.5	5.09	20.3	51.9	1,126	9.9	477	350
			STD	2.1	1.7	0.34	3.9	1.7	96	1.0	45	24
			MAX	25.0	21.8	5.60	30.3	57.0	1,256	12.1	539	387
			MIN	16.2	14.4	4.16	14.1	49.5	828	7.3	332	274
58	34.0	18	AV18	26.3	23.6	5.92	27.5	48.3	1,364	11.9	587	422
			STD	1.8	1.6	0.36	6.7	1.4	90	0.9	92	73
			MAX	29.2	26.2	6.54	38.9	50.0	1,511	13.3	726	542
			MIN	24.0	21.4	5.49	20.4	46.0	1,236	10.7	456	332
87	35.0	29	AV29	29.1	25.9	6.57	35.6	45.9	1,494	13.3	765	612
			STD	0.6	0.5	0.14	2.8	0.5	30	0.4	40	28
			MAX	30.2	27.3	6.94	39.6	46.6	1,577	14.2	854	676
			MIN	27.9	25.2	6.37	28.1	44.7	1,452	12.8	671	561
117	36.0	30	AV30	30.5	27.3	7.08	41.9	44.4	1,575	14.2	784	551
			STD	1.9	1.6	0.49	5.2	1.4	91	0.9	49	34
			MAX	33.4	29.9	7.91	50.1	46.1	1,724	15.7	864	620
			MIN	27.3	25.2	6.51	35.7	42.0	1,453	13.1	686	492

Case Method & iCAP® Results

Flatiron-Lane JV, 25ENB - 25E-2E PP30"x0.625", APE D50-52

OP: RMDT Date: 22-December-2021

BL#	Depth	BLC	TYPE	CSI	CSX	STK	EMX	BPM	FMX	VMX	RX9	RUC
	ft	bl/ft		ksi	ksi	ft	k-ft	bpm	kips	f/s	kips	kips
144	37.0	27	AV27	33.3	29.1	7.63	48.3	42.7	1,677	15.2	810	653
			STD	0.9	0.6	0.17	1.7	0.5	32	0.4	29	42
			MAX	34.6	29.9	7.93	51.1	43.9	1,722	15.8	866	712
			MIN	31.1	27.5	7.23	43.5	41.9	1,588	14.0	761	577
171	38.0	27	AV27	33.2	29.1	7.65	48.4	42.7	1,679	15.2	788	651
			STD	1.0	0.6	0.21	1.9	0.6	36	0.4	30	21
			MAX	34.9	30.2	7.96	51.8	44.0	1,743	15.8	832	692
			MIN	31.4	28.0	7.19	44.5	41.9	1,615	14.3	715	613
196	39.0	25	AV25	33.8	29.5	7.77	49.8	42.4	1,703	15.3	806	684
			STD	1.8	0.5	0.16	1.9	0.4	31	0.4	38	24
			MAX	36.8	30.4	8.06	53.6	43.3	1,754	15.9	891	740
			MIN	30.9	28.4	7.41	45.6	41.6	1,636	14.6	728	645
222	40.0	26	AV26	33.7	29.6	7.82	49.9	42.2	1,707	15.5	831	689
			STD	1.9	0.5	0.14	1.9	0.4	32	0.3	40	26
			MAX	36.6	30.6	8.06	52.9	43.0	1,766	16.1	929	746
			MIN	30.9	28.4	7.52	45.3	41.6	1,641	15.0	786	621
249	41.0	27	AV27	33.3	29.7	7.84	49.5	42.2	1,712	15.5	864	714
			STD	2.4	0.6	0.21	2.3	0.6	37	0.4	37	33
			MAX	37.0	30.9	8.24	54.9	43.1	1,780	16.3	924	801
			MIN	30.0	28.5	7.51	45.6	41.2	1,645	14.7	787	640
275	42.0	26	AV26	33.4	29.8	7.98	49.9	41.8	1,719	15.8	852	703
			STD	2.2	0.8	0.24	2.3	0.6	46	0.5	40	25
			MAX	36.7	31.5	8.38	53.3	43.2	1,819	16.7	918	743
			MIN	29.4	28.2	7.45	44.5	40.8	1,629	14.9	753	642
303	43.0	28	AV28	33.8	30.2	8.14	50.6	41.4	1,740	16.1	868	636
			STD	2.5	0.9	0.30	2.8	0.7	51	0.5	32	64

Case Method & iCAP® Results

Flatiron-Lane JV, 25ENB - 25E-2E PP30"x0.625", APE D50-52
OP: RMDT Date: 22-December-2021

BL#	Depth	BLC	TYPE	CSI	CSX	STK	EMX	BPM	FMX	VMX	RX9	RUC
	ft	bl/ft		ksi	ksi	ft	k-ft	bpm	kips	f/s	kips	kips
			MAX	39.1	32.7	8.86	58.0	43.0	1,885	17.3	936	880
			MIN	30.2	28.6	7.54	45.3	39.7	1,650	15.3	788	560
331	44.0	28	AV28	35.9	31.6	8.56	54.6	40.4	1,821	16.6	914	735
			STD	2.5	0.9	0.26	2.4	0.6	51	0.5	63	57
			MAX	39.9	33.5	9.14	59.9	41.8	1,932	17.6	1,080	807
			MIN	30.9	29.9	7.97	50.4	39.2	1,726	15.6	827	589
359	45.0	28	AV28	34.6	31.4	8.62	54.6	40.3	1,812	16.7	895	741
			STD	1.0	0.6	0.22	1.9	0.5	36	0.5	77	78
			MAX	36.6	33.2	9.21	59.7	41.6	1,914	17.5	1,061	1,090
			MIN	32.5	30.4	8.06	50.8	39.0	1,754	15.6	799	643
389	46.0	30	AV30	35.4	31.4	8.64	55.0	40.2	1,812	16.7	867	753
			STD	1.0	0.8	0.28	2.2	0.6	44	0.5	44	90
			MAX	37.3	32.7	9.03	58.2	42.0	1,885	17.4	973	1,197
			MIN	31.9	29.3	7.91	49.2	39.4	1,688	15.6	800	647
420	47.0	31	AV31	35.8	31.6	8.70	55.7	40.1	1,824	16.7	926	790
			STD	0.8	0.7	0.23	1.9	0.5	42	0.4	59	45
			MAX	37.1	32.8	9.13	58.6	41.4	1,894	17.4	1,038	872
			MIN	33.7	29.8	8.15	51.6	39.2	1,716	16.0	797	660
451	48.0	31	AV31	36.0	31.7	8.73	55.9	40.0	1,830	16.8	952	835
			STD	0.8	0.5	0.14	1.5	0.3	30	0.3	75	24
			MAX	37.3	32.5	8.94	58.4	40.8	1,876	17.4	1,102	928
			MIN	34.5	30.8	8.40	52.7	39.6	1,779	16.1	836	807
482	49.0	31	AV31	37.2	32.2	8.79	56.3	39.9	1,856	17.0	946	808
			STD	1.1	0.7	0.18	1.6	0.4	38	0.3	59	28
			MAX	39.1	33.4	9.15	59.3	40.9	1,926	17.4	1,110	894
			MIN	35.5	31.1	8.34	52.5	39.1	1,795	16.1	858	735

Case Method & iCAP® Results

Flatiron-Lane JV, 25ENB - 25E-2E PP30"x0.625", APE D50-52
OP: RMDT Date: 22-December-2021

BL#	Depth	BLC	TYPE	CSI	CSX	STK	EMX	BPM	FMX	VMX	RX9	RUC
	ft	bl/ft		ksi	ksi	ft	k-ft	bpm	kips	f/s	kips	kips
514	50.0	32	AV32	38.2	32.3	8.79	56.2	39.9	1,863	17.0	911	802
			STD	0.8	0.7	0.22	1.9	0.5	38	0.4	34	15
			MAX	39.4	33.2	9.09	59.5	41.5	1,916	17.7	983	830
			MIN	36.3	30.7	8.10	50.8	39.3	1,769	15.5	855	771
546	51.0	32	AV27	38.1	31.9	8.84	56.0	39.8	1,842	16.8	885	807
			STD	0.8	0.7	0.19	2.6	0.4	38	0.4	33	26
			MAX	39.5	32.9	9.15	58.5	40.9	1,900	17.5	940	859
			MIN	35.8	30.1	8.34	44.8	39.1	1,733	16.0	780	717
578	52.0	32	AV31	37.0	31.2	8.88	56.4	39.7	1,800	16.6	867	835
			STD	1.5	0.7	0.34	1.9	0.7	43	0.5	47	44
			MAX	39.4	33.7	9.98	60.3	41.1	1,944	17.6	1,025	910
			MIN	33.1	29.4	8.27	52.4	37.5	1,695	15.5	798	758
607	53.0	29	AV29	37.3	31.0	8.67	55.3	40.2	1,786	16.6	805	751
			STD	0.7	0.7	0.24	3.0	0.6	38	0.5	37	17
			MAX	38.5	32.2	9.08	58.8	41.7	1,856	17.3	929	777
			MIN	36.0	29.4	8.03	42.6	39.3	1,697	15.6	732	720

BL# Sensors

2-607 F2: [H895] 91.3 (1.00); F3: [M095] 151.8 (1.00); A1: [K5182] 345.0 (1.00); A4: off

BL# Comments

1 Start of test on 12/22/2021 at 10:24 PM
607 End of test on 12/22/2021 at 10:40 PM

Case Method & iCAP® Results

Flatiron-Lane JV, 25ENB - 25E-2E PP30"x0.625", APE D50-52
OP: RMDT Date: 22-December-2021

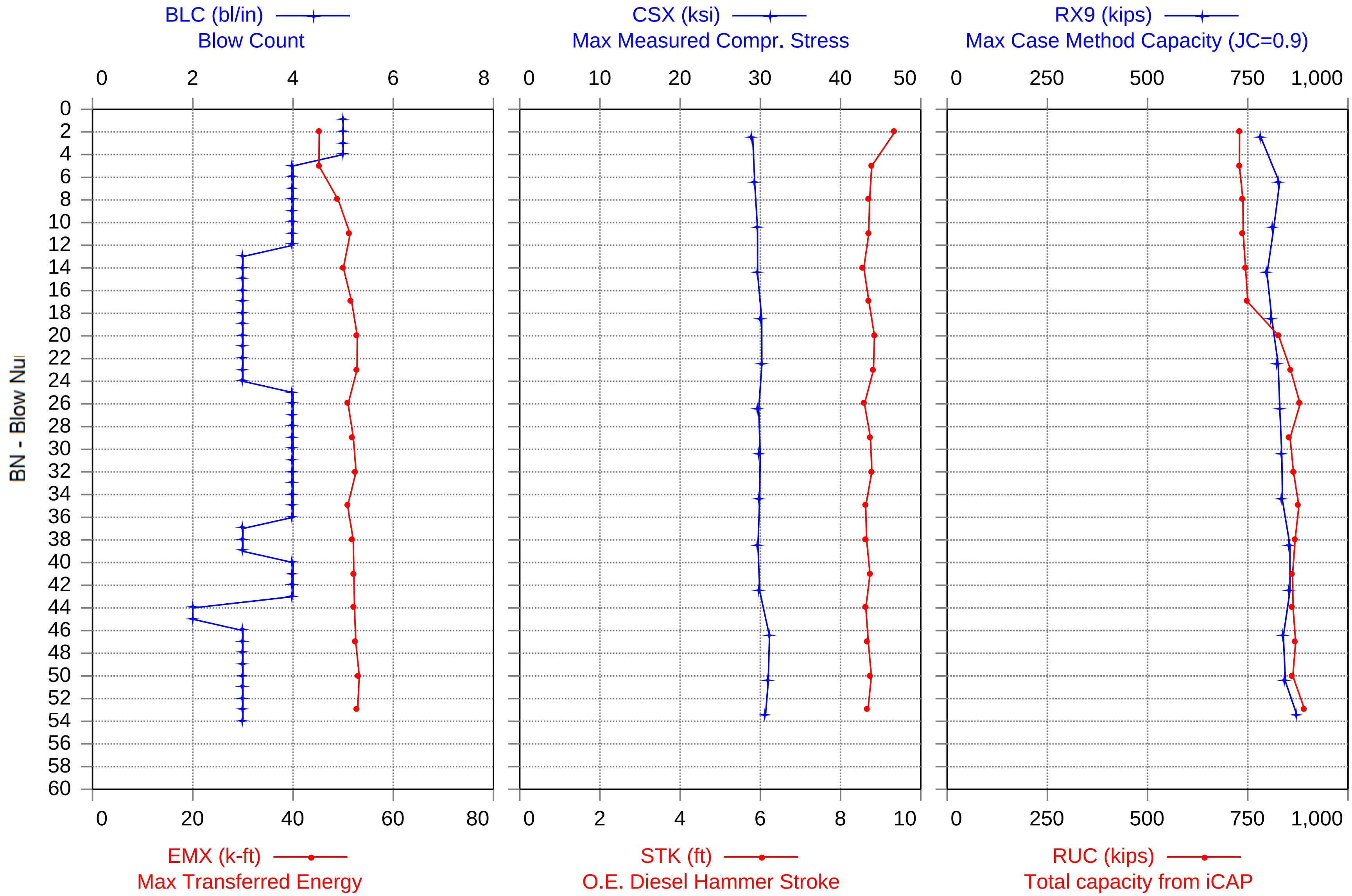
Time Summary

Drive 15 minutes 49 seconds 10:24 PM - 10:40 PM BN 1 - 607

Robert Miner Dynamic Testing, Inc. - PDIPLOT2 Ver 2021.1.61.0 - Case Method & iCAP® Results

Printed: 03-January-2022 Test started: 03-January-2022

Flatiron-Lane JV, 25ENB - 25E-2E RESTRIKE



Case Method & iCAP® Results

Flatiron-Lane JV, 25ENB - 25E-2E RESTRIKE PP30"x0.625", APE D50-52

OP: RMDT Date: 03-January-2022

AR: 57.68 in²		SP: 0.492 k/ft³	
LE: 55.00 ft		EM: 30,000 ksi	
WS: 16,807.9 f/s		JC: 0.90	

CSI: Max F1 or F2 Compr. Stress
CSX: Max Measured Compr. Stress
STK: O.E. Diesel Hammer Stroke
EMX: Max Transferred Energy
BPM: Blows per Minute
FMX: Maximum Force
VMX: Maximum Velocity
RX9: Max Case Method Capacity (JC=0.9)
RUC: Total capacity from iCAP

BL#	Depth	BLC	TYPE	CSI	CSX	STK	EMX	BPM	FMX	VMX	RX9	RUC
	ft	bl/in		ksi	ksi	ft	k-ft	bpm	kips	f/s	kips	kips
4	53.50	5	AV4	38.8	29.0	9.35	46.9	38.8	1,675	15.1	783	728
			STD	1.8	2.2	0.39	4.4	0.8	125	0.9	75	37
			MAX	41.6	31.8	9.82	52.0	40.0	1,834	16.3	876	774
			MIN	36.9	25.9	8.74	40.8	37.8	1,496	13.8	668	673
8	53.58	4	AV4	36.5	29.3	8.67	46.9	40.2	1,690	15.2	829	743
			STD	2.4	1.4	0.31	5.6	0.7	81	0.8	16	19
			MAX	39.5	31.4	9.19	55.0	40.7	1,811	16.3	857	773
			MIN	32.9	27.5	8.46	40.9	39.0	1,585	14.2	816	722
12	53.67	4	AV4	35.2	29.6	8.65	49.2	40.2	1,709	15.5	815	730
			STD	1.1	0.9	0.13	3.9	0.3	54	0.4	19	19
			MAX	37.0	30.6	8.82	53.1	40.6	1,763	16.0	836	751
			MIN	34.2	28.3	8.50	42.8	39.9	1,631	15.0	787	704
15	53.75	3	AV3	38.0	29.6	8.58	50.0	40.4	1,707	15.4	807	744
			STD	2.0	1.2	0.36	3.6	0.8	70	0.6	7	10
			MAX	40.2	31.3	9.05	54.9	41.4	1,805	16.3	813	753
			MIN	35.4	28.7	8.16	46.5	39.4	1,653	15.0	797	730
18	53.83	3	AV3	36.0	29.9	8.71	51.7	40.1	1,724	15.6	795	750
			STD	3.4	0.5	0.14	1.5	0.3	27	0.4	17	6
			MAX	38.8	30.5	8.86	53.8	40.5	1,760	16.1	813	755
			MIN	31.2	29.4	8.52	50.2	39.7	1,694	15.1	772	741

Case Method & iCAP® Results

Flatiron-Lane JV, 25ENB - 25E-2E RESTRIKE PP30"x0.625", APE D50-52

OP: RMDT Date: 03-January-2022

BL#	Depth	BLC	TYPE	CSI	CSX	STK	EMX	BPM	FMX	VMX	RX9	RUC
	ft	bl/in		ksi	ksi	ft	k-ft	bpm	kips	f/s	kips	kips
21	53.92	3	AV3	37.0	30.3	8.84	52.8	39.8	1,750	15.8	812	827
			STD	2.2	0.3	0.08	0.4	0.2	15	0.1	8	31
			MAX	39.0	30.7	8.96	53.3	40.0	1,770	15.9	823	850
			MIN	33.9	30.1	8.76	52.4	39.6	1,736	15.8	803	782
24	54.00	3	AV3	36.8	30.2	8.82	52.8	39.8	1,740	15.9	831	857
			STD	1.6	0.4	0.16	1.9	0.4	22	0.4	21	10
			MAX	39.1	30.6	8.96	54.9	40.3	1,767	16.3	859	870
			MIN	35.6	29.7	8.59	50.4	39.5	1,713	15.4	808	846
28	54.08	4	AV4	36.5	29.8	8.70	51.8	40.1	1,719	15.7	830	874
			STD	1.0	0.4	0.19	1.4	0.4	23	0.3	8	16
			MAX	38.2	30.2	9.02	54.1	40.5	1,743	16.0	842	898
			MIN	35.8	29.2	8.55	50.6	39.4	1,686	15.3	821	853
32	54.17	4	AV4	36.1	30.0	8.67	51.5	40.2	1,729	15.8	835	859
			STD	0.4	0.5	0.15	1.4	0.3	27	0.3	18	9
			MAX	36.8	30.6	8.86	53.1	40.6	1,766	16.1	857	868
			MIN	35.7	29.5	8.47	49.5	39.7	1,699	15.3	808	845
36	54.25	4	AV4	35.7	29.9	8.69	51.6	40.1	1,724	15.6	836	875
			STD	1.5	0.5	0.12	1.4	0.3	28	0.1	9	7
			MAX	36.6	30.6	8.86	53.7	40.5	1,763	15.8	850	887
			MIN	33.2	29.4	8.54	49.7	39.7	1,695	15.4	824	868
39	54.33	3	AV3	35.6	29.7	8.65	52.0	40.2	1,711	15.7	853	868
			STD	0.7	0.3	0.04	1.1	0.1	17	0.2	12	19
			MAX	36.3	30.0	8.71	53.5	40.3	1,733	16.0	867	889
			MIN	34.8	29.3	8.60	51.0	40.1	1,692	15.4	839	843
43	54.42	4	AV4	35.5	29.8	8.66	51.6	40.2	1,716	15.5	858	859
			STD	0.8	0.6	0.18	1.3	0.4	37	0.2	9	12

Case Method & iCAP® Results

Flatiron-Lane JV, 25ENB - 25E-2E RESTRIKE PP30"x0.625", APE D50-52

OP: RMDT Date: 03-January-2022

BL#	Depth	BLC	TYPE	CSI	CSX	STK	EMX	BPM	FMX	VMX	RX9	RUC
	ft	bl/in		ksi	ksi	ft	k-ft	bpm	kips	f/s	kips	kips
			MAX	36.6	30.8	8.91	53.3	40.7	1,776	15.7	870	876
			MIN	34.5	29.2	8.43	50.1	39.6	1,682	15.1	845	844
45	54.50	2	AV2	36.5	31.0	8.73	53.3	40.0	1,788	15.8	828	869
			STD	0.3	0.6	0.10	0.6	0.2	33	0.2	20	4
			MAX	36.9	31.6	8.83	54.0	40.3	1,822	15.9	848	873
			MIN	36.2	30.4	8.63	52.7	39.8	1,755	15.6	808	865
48	54.58	3	AV3	36.0	31.0	8.69	52.5	40.1	1,787	15.6	849	869
			STD	0.5	0.2	0.06	0.5	0.1	9	0.1	10	6
			MAX	36.5	31.2	8.78	53.1	40.2	1,799	15.7	859	874
			MIN	35.3	30.8	8.65	51.9	39.9	1,776	15.4	835	860
51	54.67	3	AV3	36.5	31.1	8.77	53.2	40.0	1,791	15.7	847	862
			STD	0.5	0.3	0.06	0.6	0.1	19	0.1	9	18
			MAX	37.1	31.4	8.85	53.9	40.1	1,812	15.7	858	887
			MIN	35.9	30.6	8.69	52.4	39.8	1,766	15.6	836	844
54	54.75	3	AV3	35.2	30.7	8.68	52.9	40.2	1,768	15.7	860	892
			STD	0.4	0.2	0.07	0.5	0.2	11	0.2	30	17
			MAX	35.5	30.9	8.76	53.6	40.3	1,780	15.9	901	915
			MIN	34.6	30.4	8.59	52.3	40.0	1,753	15.5	834	875

BL# Sensors

1-54 F2: [H895] 91.3 (1.00); F3: [V884] 91.9 (1.00); A1: [K5182] 345.0 (1.00); A4: [K3260] 357.0 (1.00)

BL# Comments

1 Start of test on 1/3/2022 at 1:54 PM

54 End of test on 1/3/2022 at 1:56 PM

Time Summary

Drive 1 minute 19 seconds 1:54 PM - 1:56 PM BN 1 - 54

Case Method & iCAP® Results

Flatiron-Lane JV, 25ENB - 25E-2E RESTRIKE PP30"x0.625", APE D50-52
OP: RMDT Date: 03-January-2022

AR: 57.68 in² SP: 0.492 k/ft³
LE: 55.00 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.90

CSI: Max F1 or F2 Compr. Stress
CSX: Max Measured Compr. Stress
STK: O.E. Diesel Hammer Stroke
EMX: Max Transferred Energy
BPM: Blows per Minute
FMX: Maximum Force
VMX: Maximum Velocity
RX9: Max Case Method Capacity (JC=0.9)
RUC: Total capacity from iCAP

BL#	Depth	BLC	TYPE	CSI	CSX	STK	EMX	BPM	FMX	VMX	RX9	RUC
	ft	bl/ft		ksi	ksi	ft	k-ft	bpm	kips	f/s	kips	kips
43	54.42	43	AV43	36.5	29.7	8.75	50.6	40.0	1,715	15.6	824	809
			STD	2.0	1.0	0.30	3.5	0.6	59	0.5	34	65
			MAX	41.6	31.8	9.82	55.1	41.4	1,834	16.3	872	898
			MIN	31.2	25.9	8.16	41.0	37.8	1,496	13.8	663	673
54	54.75	33	AV11	36.0	30.9	8.72	52.9	40.1	1,783	15.7	847	873
			STD	0.7	0.4	0.08	0.6	0.2	21	0.1	20	18
			MAX	37.1	31.6	8.85	54.0	40.3	1,822	15.9	900	915
			MIN	34.6	30.4	8.59	52.0	39.8	1,753	15.4	816	844

BL# Sensors

1-54 F2: [H895] 91.3 (1.00); F3: [V884] 91.9 (1.00); A1: [K5182] 345.0 (1.00); A4: [K3260] 357.0 (1.00)

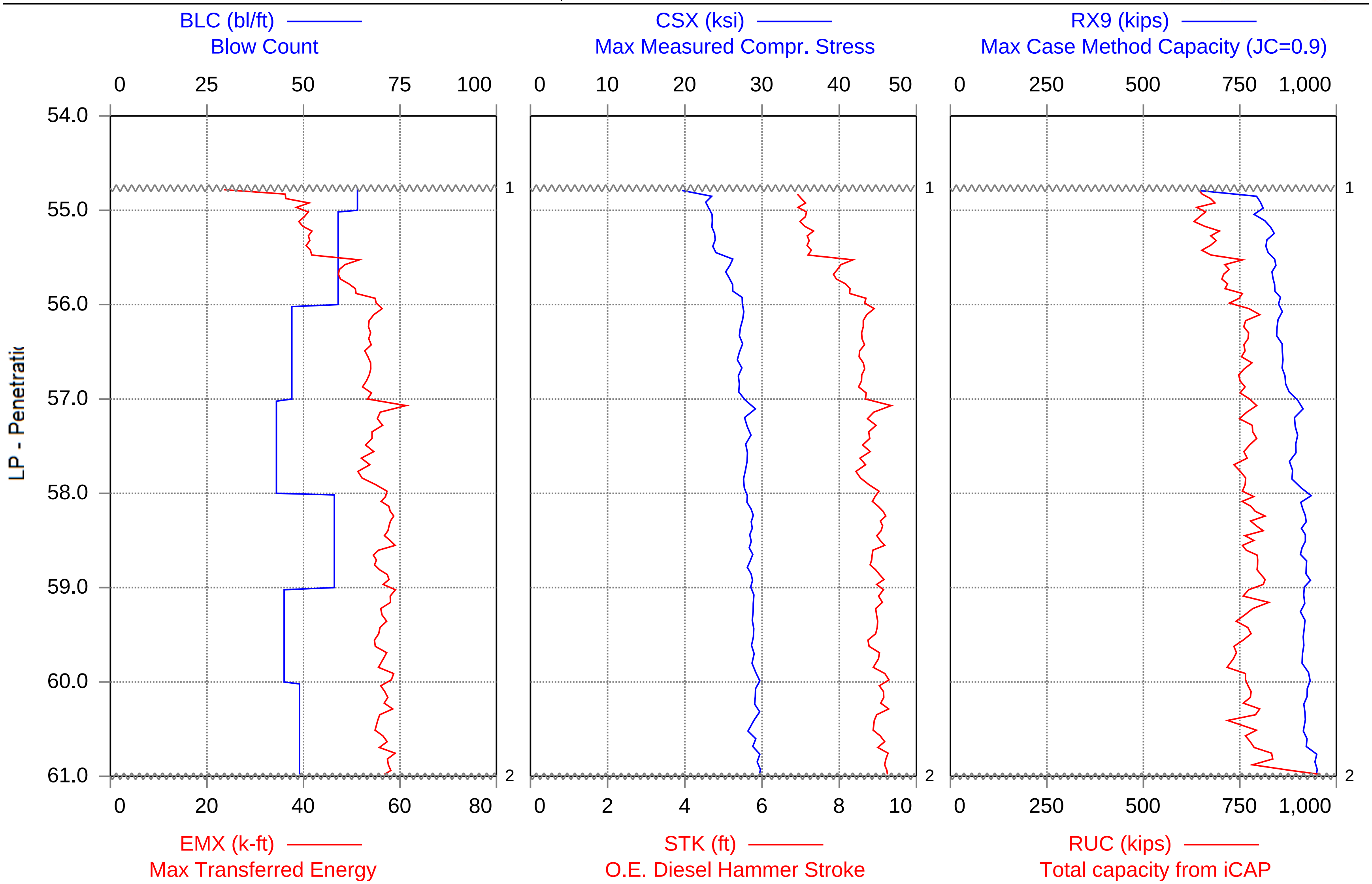
BL# Comments

1 Start of test on 1/3/2022 at 1:54 PM
54 End of test on 1/3/2022 at 1:56 PM

Time Summary

Drive 1 minute 19 seconds 1:54 PM - 1:56 PM BN 1 - 54

Robert Miner Dynamic Testing, Inc. - PDIPLOT2 Ver 2021.1.61.0 - Case Method & iCAP® Results
Printed: 06-January-2022 Test started: 06-January-2022
Flatiron-Lane JV, 25ENB - 25E-2E Drive B



1 - Start of test on 1/6/2022 at 11:36 AM
2 - End of test on 1/6/2022 at 11:45 AM

Case Method & iCAP® Results

Flatiron-Lane JV, 25ENB - 25E-2E Drive B PP30"x0.625", APE D50-52

OP: RMDT Date: 06-January-2022

AR: 57.68 in² SP: 0.492 k/ft³
LE: 108.50 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.90

CSI: Max F1 or F2 Compr. Stress
CSX: Max Measured Compr. Stress
STK: O.E. Diesel Hammer Stroke
EMX: Max Transferred Energy
BPM: Blows per Minute
FMX: Maximum Force
VMX: Maximum Velocity
RX9: Max Case Method Capacity (JC=0.9)
RUC: Total capacity from iCAP

BL#	Depth	BLC	TYPE	CSI	CSX	STK	EMX	BPM	FMX	VMX	RX9	RUC
	ft	bl/ft		ksi	ksi	ft	k-ft	bpm	kips	f/s	kips	kips
16	55.0	64	AV16	26.6	22.2	7.01	35.5	36.6	1,282	12.6	762	659
			STD	3.6	1.9	0.43	7.4	16.7	108	1.3	75	35
			MAX	35.9	25.2	7.72	44.5	47.6	1,456	14.4	829	714
			MIN	22.2	18.9	6.08	22.1	1.9	1,092	10.5	621	601
75	56.0	59	AV59	25.7	25.1	7.71	45.6	42.6	1,445	14.3	831	696
			STD	1.5	1.5	0.61	5.5	1.6	88	1.0	19	41
			MAX	28.3	27.9	8.84	56.9	45.5	1,608	16.1	863	798
			MIN	22.5	22.1	6.68	37.6	39.8	1,276	12.5	768	625
122	57.0	47	AV47	27.7	27.2	8.63	53.7	40.3	1,570	15.6	860	765
			STD	0.6	0.5	0.22	1.8	0.5	31	0.3	13	23
			MAX	29.0	28.4	9.08	57.5	41.6	1,636	16.4	887	829
			MIN	26.3	25.9	8.09	48.5	39.3	1,494	14.8	830	718
165	58.0	43	AV43	29.1	28.1	8.78	54.7	40.0	1,620	15.7	896	768
			STD	0.8	0.7	0.28	2.8	0.6	40	0.4	17	24
			MAX	31.3	30.3	9.82	63.5	41.1	1,750	16.8	931	820
			MIN	27.1	26.6	8.27	50.3	37.8	1,534	14.9	864	727
223	59.0	58	AV58	29.2	28.5	9.01	57.0	39.4	1,644	16.2	919	789
			STD	0.8	0.5	0.19	1.8	0.4	29	0.3	16	29
			MAX	31.7	29.8	9.34	60.7	40.7	1,719	16.8	957	847
			MIN	27.7	27.6	8.43	52.0	38.8	1,591	15.4	891	696

Case Method & iCAP® Results

Flatiron-Lane JV, 25ENB - 25E-2E Drive B PP30"x0.625", APE D50-52

OP: RMDT Date: 06-January-2022

BL#	Depth	BLC	TYPE	CSI	CSX	STK	EMX	BPM	FMX	VMX	RX9	RUC
	ft	bl/ft		ksi	ksi	ft	k-ft	bpm	kips	f/s	kips	kips
268	60.0	45	AV44	30.5	28.9	9.00	56.8	39.5	1,668	16.1	917	759
			STD	1.0	0.6	0.20	1.9	0.4	34	0.4	12	41
			MAX	32.6	30.3	9.40	61.3	40.4	1,747	16.8	949	840
			MIN	28.0	27.7	8.55	52.8	38.6	1,600	15.4	895	665
317	61.0	49	AV46	30.9	29.2	9.11	56.9	39.2	1,685	16.2	928	794
			STD	1.4	0.8	0.22	1.9	0.5	44	0.3	19	53
			MAX	33.4	30.9	9.58	60.9	40.4	1,783	16.8	968	959
			MIN	27.9	27.5	8.59	52.8	38.3	1,586	15.3	888	658

BL#	Sensors
1-316	F2: [H895] 91.3 (1.00); F3: [V884] 91.9 (1.00); A1: [K5182] 345.0 (1.00); A4: [K3260] 357.0 (1.00)

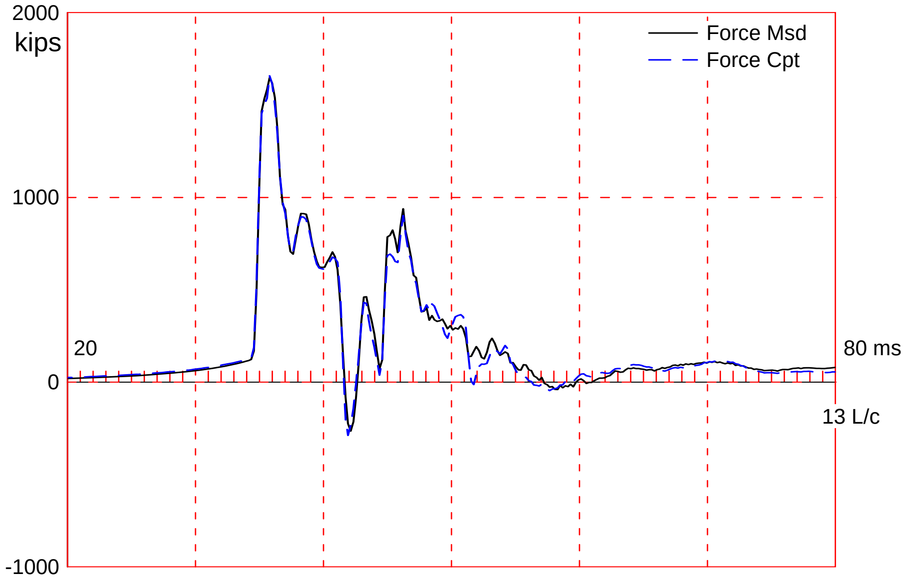
BL#	Comments
1	Start of test on 1/6/2022 at 11:36 AM
317	End of test on 1/6/2022 at 11:45 AM

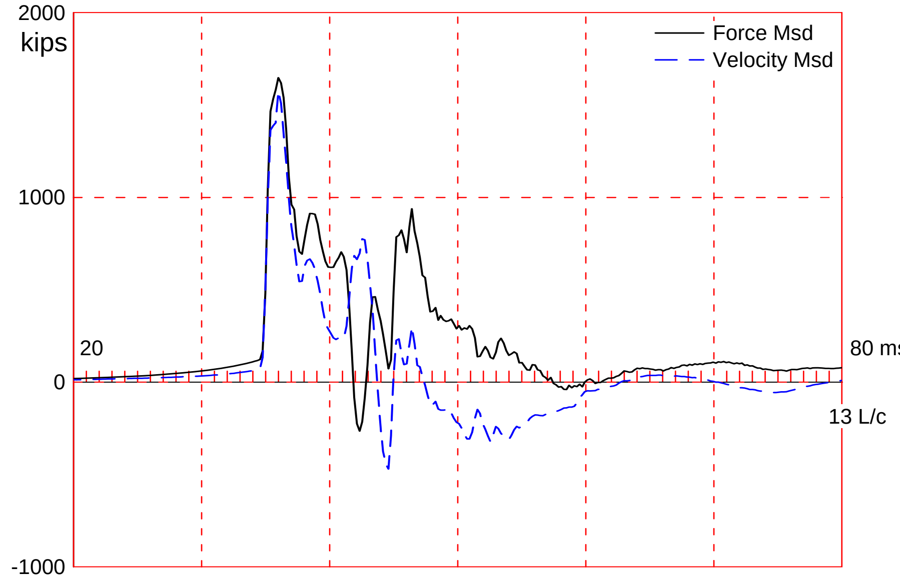
Time Summary

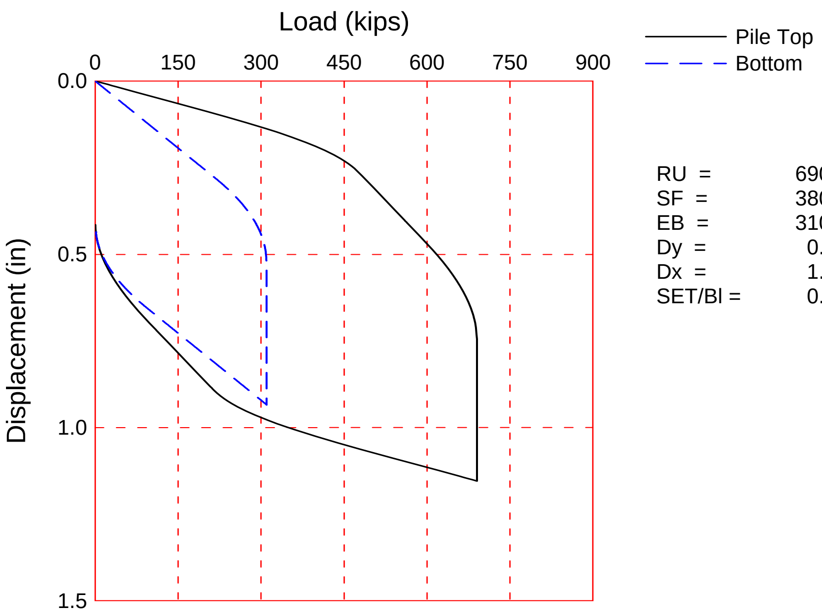
Drive 9 minutes 1 second 11:36 AM - 11:45 AM BN 1 - 317

Appendix C

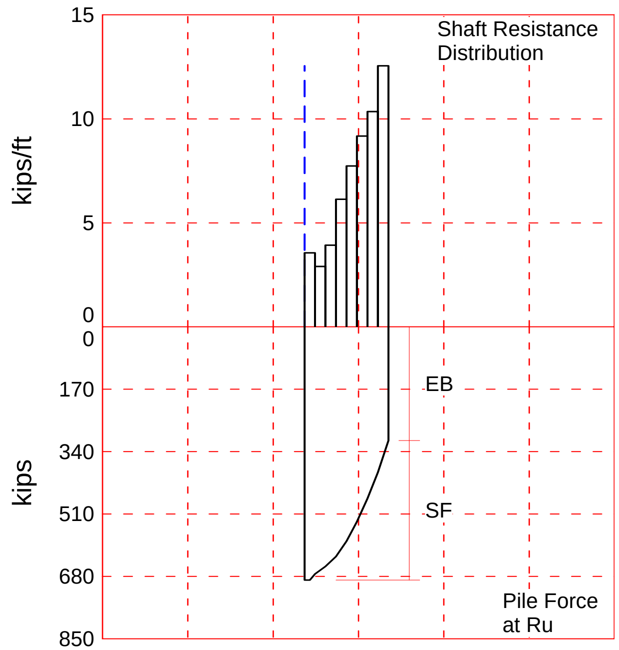
Summary of CAPWAP Results







RU =	690.1 kips
SF =	380.1 kips
EB =	310.0 kips
Dy =	0.74 in
Dx =	1.15 in
SET/Bl =	0.41 in



Length b. Sensors	55.0 ft
Embedment	52.9 ft
Top Area	57.7 in²
End Bearing Area	57.7 in²
Top Perimeter	7.85 ft
Top E-Modulus	30000 ksi
Top Spec. Weight	492.0 lb/ft³
Top Wave Spd.	16808 ft/s
Overall W.S.	16808 ft/s
Match Quality	3.32
Top Compr. Stress	28.9 ksi
Max Compr. Stress	29.0 ksi
Max Tension Stress	-3.50 ksi
Avg. Shaft Quake	0.10 in
Toe Quake	0.40 in
Avg. Shaft Smith Dpg.	0.07 s/ft
Toe Smith Damping	0.09 s/ft

CAPWAP SUMMARY RESULTS

Total CAPWAP Capacity: 690.1; along Shaft 380.1; at Toe 310.0 kips

Soil Sgmnt No.	Dist. Below Gages ft	Depth Below Grade ft	Ru kips	Force in Pile kips	Sum of Ru kips	Unit Resist. (Depth) kips/ft	Unit Resist. (Area) ksf
				690.1			
1	6.9	4.8	17.1	673.0	17.1	3.56	0.45
2	13.8	11.7	20.0	653.0	37.1	2.91	0.37
3	20.6	18.6	27.0	626.0	64.1	3.93	0.50
4	27.5	25.4	42.2	583.8	106.3	6.14	0.78
5	34.4	32.3	53.2	530.6	159.5	7.74	0.99
6	41.3	39.2	63.1	467.5	222.6	9.18	1.17
7	48.1	46.1	71.2	396.3	293.8	10.36	1.32
8	55.0	52.9	86.3	310.0	380.1	12.55	1.60
Avg. Shaft			47.5			7.18	0.91
Toe			310.0				773.66

Soil Model Parameters/Extensions		Shaft	Toe
Smith Damping Factor		0.07	0.09
Quake	(in)	0.10	0.40
Case Damping Factor		0.26	0.27
Damping Type		Viscous	Sm+Visc
Unloading Quake	(% of loading quake)	30	80
Reloading Level	(% of Ru)	100	100
Unloading Level	(% of Ru)	45	
Soil Plug Weight	(kips)		0.030

CAPWAP match quality = 3.32 (Wave Up Match) ; RSA = 0
Observed: Final Set = 0.41 in; Blow Count = 29 b/ft
Computed: Final Set = 0.46 in; Blow Count = 26 b/ft

max. Top Comp. Stress = 28.9 ksi (T= 36.2 ms, max= 1.005 x Top)
max. Comp. Stress = 29.0 ksi (Z= 6.9 ft, T= 36.4 ms)
max. Tens. Stress = -3.50 ksi (Z= 3.4 ft, T= 42.3 ms)
max. Energy (EMX) = 54.7 kip-ft; max. Measured Top Displ. (DMX)= 0.76 in

EXTREMA TABLE

Pile Sgmnt No.	Dist. Below Gages ft	max. Force kips	min. Force kips	max. Comp. Stress ksi	max. Tens. Stress ksi	max. Trnsfd. Energy kip-ft	max. Veloc. ft/s	max. Displ. in
1	3.4	1666.8	-202.0	28.9	-3.50	54.7	15.1	0.76
2	6.9	1674.8	-52.2	29.0	-0.90	54.4	15.0	0.75
3	10.3	1648.5	-73.5	28.6	-1.27	52.5	14.9	0.73
4	13.8	1658.9	-99.8	28.8	-1.73	52.1	14.8	0.72
5	17.2	1629.8	-119.9	28.3	-2.08	50.1	14.6	0.71
6	20.6	1645.7	-72.0	28.5	-1.25	49.9	14.5	0.70
7	24.1	1607.3	-26.4	27.9	-0.46	47.3	14.3	0.69
8	27.5	1628.1	-9.6	28.2	-0.17	47.0	14.1	0.67
9	30.9	1564.5	0.0	27.1	0.00	43.0	13.9	0.66
10	34.4	1589.2	-62.7	27.6	-1.09	42.6	13.6	0.65
11	37.8	1507.8	-126.1	26.1	-2.19	38.2	13.4	0.65
12	41.3	1535.6	-30.9	26.6	-0.53	38.1	14.2	0.64
13	44.7	1407.9	-31.9	24.4	-0.55	32.9	17.8	0.63
14	48.1	1290.6	0.0	22.4	0.00	32.8	20.3	0.63
15	51.6	925.8	0.0	16.1	0.00	26.7	20.3	0.62
16	55.0	710.8	0.0	12.3	0.00	20.0	19.4	0.61
Absolute	6.9			29.0			(T =	36.4 ms)
	3.4				-3.50		(T =	42.3 ms)

CASE METHOD

J =	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
RP	1396.0	1201.9	1007.8	813.8	619.7	425.6	231.6	37.5	0.0	0.0
RX	1396.0	1201.9	1121.6	1065.7	1009.9	954.0	920.2	900.6	881.1	861.5
RU	1396.0	1201.9	1007.8	813.8	619.7	425.6	231.6	37.5	0.0	0.0

RAU = 566.3 (kips); RA2 = 839.9 (kips)

Current CAPWAP Ru = 690.1 (kips); Corresponding J(RP)= 0.36;

RMX requires higher damping; see PDA-W

VMX ft/s	TVP ms	VT1*Z kips	FT1 kips	FMX kips	DMX in	DFN in	SET in	EMX kip-ft	QUS kips	KEB kips/in
16.6	36.00	1696.3	1640.4	1747.5	0.76	0.41	0.41	54.7	1118.2	775

PILE PROFILE AND PILE MODEL

Depth ft	Area in^2	E-Modulus ksi	Spec. Weight lb/ft^3	Perim. ft
0.0	57.7	30000.0	492.000	7.85
55.0	57.7	30000.0	492.000	7.85

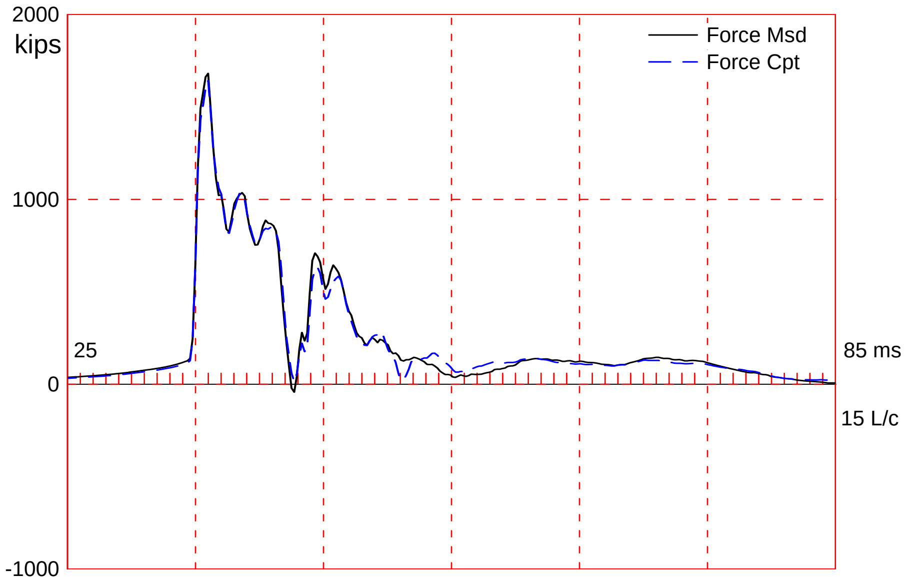
Toe Area 57.7 in^2

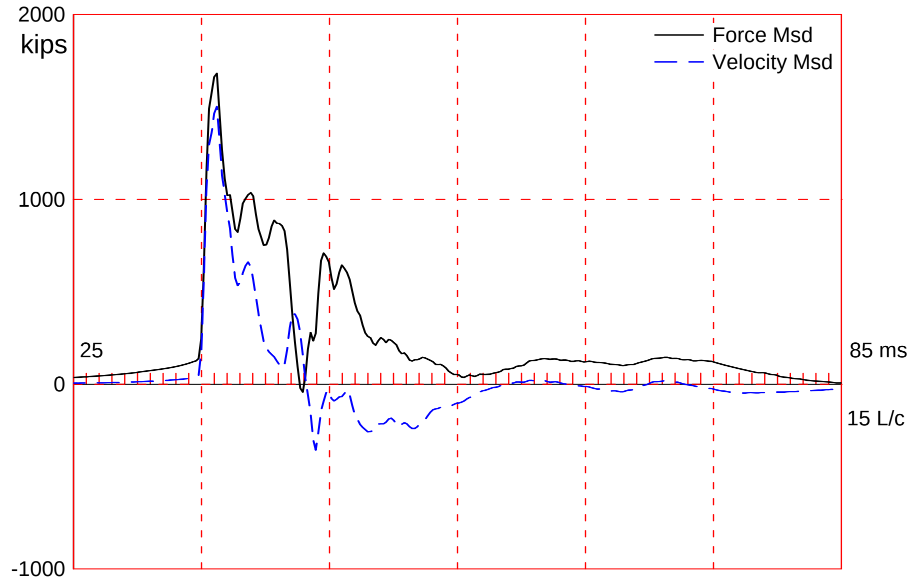
Top Segment Length 3.44 ft, Top Impedance 103 kips/ft/s

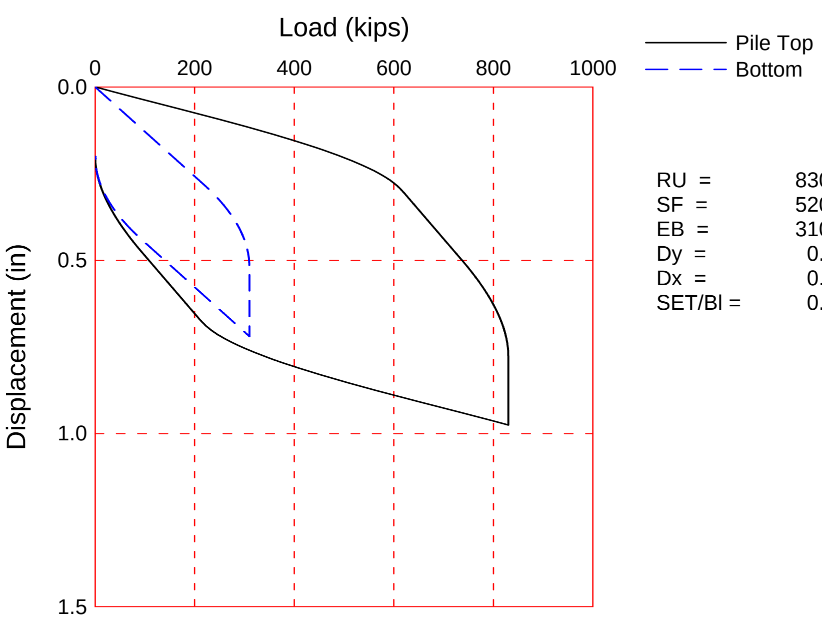
Wave Speed: Pile Top 16807.9, Elastic 16807.9, Overall 16807.9 ft/s
Pile Damping 1.00 %, Time Incr 0.205 ms, 2L/c 6.5 ms
Total volume: 22.030 ft^3; Volume ratio considering added impedance: 1.000

Flatiron-Lane JV, 25ENB; Pile: 25E-2E RESTRIKE; PP30"x0.625", APE D50-52; Blow: 3 (Test: 03-Jan-2022 13:54:)
Robert Miner Dynamic Testing, Inc.

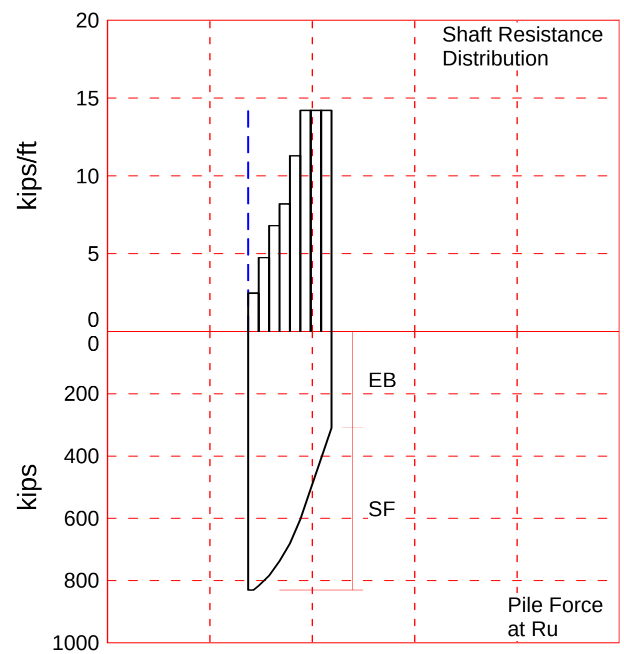
05-Jan-2022
CAPWAP(R) 2014-3







RU =	830.0 kips
SF =	520.0 kips
EB =	310.0 kips
Dy =	0.78 in
Dx =	0.98 in
SET/Bl =	0.20 in



Length b. Sensors	55.0 ft
Embedment	53.5 ft
Top Area	57.7 in^2
End Bearing Area	57.7 in^2
Top Perimeter	7.85 ft
Top E-Modulus	30000 ksi
Top Spec. Weight	492.0 lb/ft^3
Top Wave Spd.	16808 ft/s
Overall W.S.	16901 ft/s
Match Quality	2.94
Top Compr. Stress	28.7 ksi
Max Compr. Stress	29.4 ksi
Max Tension Stress	-0.40 ksi
Avg. Shaft Quake	0.10 in
Toe Quake	0.40 in
Avg. Shaft Smith Dpg.	0.15 s/ft
Toe Smith Damping	0.05 s/ft

CAPWAP SUMMARY RESULTS

Total CAPWAP Capacity: 830.0; along Shaft 520.0; at Toe 310.0 kips

Soil Sgmnt No.	Dist. Below Gages ft	Depth Below Grade ft	Ru kips	Force in Pile kips	Sum of Ru kips	Unit Resist. (Depth) kips/ft	Unit Resist. (Area) ksf
				830.0			
1	6.9	5.4	13.3	816.7	13.3	2.48	0.32
2	13.8	12.2	32.7	784.0	46.0	4.76	0.61
3	20.6	19.1	46.8	737.2	92.8	6.81	0.87
4	27.5	26.0	56.4	680.8	149.2	8.20	1.04
5	34.4	32.9	77.7	603.1	226.9	11.30	1.44
6	41.3	39.7	97.7	505.4	324.6	14.21	1.81
7	48.1	46.6	97.7	407.7	422.3	14.21	1.81
8	55.0	53.5	97.7	310.0	520.0	14.21	1.81
Avg. Shaft			65.0			9.72	1.24
Toe			310.0				773.97

Soil Model Parameters/Extensions		Shaft	Toe
Smith Damping Factor		0.15	0.05
Quake	(in)	0.10	0.40
Case Damping Factor		0.76	0.15
Damping Type		Viscous	Sm+Visc
Unloading Quake	(% of loading quake)	40	50
Reloading Level	(% of Ru)	100	100
Unloading Level	(% of Ru)	10	
Soil Plug Weight	(kips)		0.360

CAPWAP match quality = 2.94 (Wave Up Match) ; RSA = 0
Observed: Final Set = 0.20 in; Blow Count = 60 b/ft
Computed: Final Set = 0.22 in; Blow Count = 53 b/ft
Transducer F2 (H895) CAL: 91.3; RF: 1.00; F3 (V884) CAL: 91.9; RF: 1.00
A1 (K5182) CAL: 345; RF: 1.00; A4 (K3260) CAL: 357; RF: 1.00

max. Top Comp. Stress = 28.7 ksi (T= 36.4 ms, max= 1.024 x Top)
max. Comp. Stress = 29.4 ksi (Z= 13.8 ft, T= 37.0 ms)
max. Tens. Stress = -0.40 ksi (Z= 6.9 ft, T= 157.6 ms)
max. Energy (EMX) = 49.5 kip-ft; max. Measured Top Displ. (DMX)= 0.56 in

EXTREMA TABLE

Pile Sgmnt No.	Dist. Below Gages ft	max. Force kips	min. Force kips	max. Comp. Stress ksi	max. Tens. Stress ksi	max. Trnsfd. Energy kip-ft	max. Veloc. ft/s	max. Displ. in
1	3.4	1654.3	-23.1	28.7	-0.40	49.5	14.9	0.57
2	6.9	1679.3	-23.3	29.1	-0.40	49.5	14.6	0.57
3	10.3	1658.2	-22.0	28.7	-0.38	48.0	14.4	0.56
4	13.8	1693.9	-22.0	29.4	-0.38	47.8	14.1	0.55
5	17.2	1620.5	-18.7	28.1	-0.32	44.5	13.8	0.54
6	20.6	1663.4	-19.0	28.8	-0.33	44.1	13.4	0.52
7	24.1	1555.6	-14.3	27.0	-0.25	39.9	13.0	0.51
8	27.5	1609.9	-14.4	27.9	-0.25	39.7	12.5	0.50
9	30.9	1488.1	-8.9	25.8	-0.15	35.0	12.1	0.49
10	34.4	1552.9	-9.0	26.9	-0.16	34.7	11.5	0.47
11	37.8	1386.6	-1.6	24.0	-0.03	28.7	11.1	0.46
12	41.3	1451.4	-1.7	25.2	-0.03	28.3	10.5	0.45
13	44.7	1228.3	-0.0	21.3	-0.00	21.3	10.3	0.44
14	48.1	1156.6	-0.0	20.1	-0.00	21.1	12.6	0.43
15	51.6	858.6	-0.0	14.9	-0.00	14.2	15.0	0.42
16	55.0	500.8	-0.0	8.7	-0.00	7.0	15.0	0.41
Absolute	13.8			29.4			(T =	37.0 ms)
	6.9				-0.40		(T =	157.6 ms)

CASE METHOD

J =	0.0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8
RP	1447.0	1090.0	733.0	375.9	18.9					
RX	1447.0	1124.2	1039.0	953.8	900.9	851.9	802.9	753.8	704.8	655.8
RU	1447.0	1090.0	733.0	375.9	18.9					

RAU = 456.5 (kips); RA2 = 1109.1 (kips)

Current CAPWAP Ru = 830.0 (kips); Corresponding J(RP)= 0.35; J(RX) = 1.09

VMX ft/s	TVP ms	VT1*Z kips	FT1 kips	FMX kips	DMX in	DFN in	SET in	EMX kip-ft	QUS kips	KEB kips/in
15.5	36.20	1591.2	1641.0	1735.3	0.56	0.19	0.20	49.8	1569.9	775

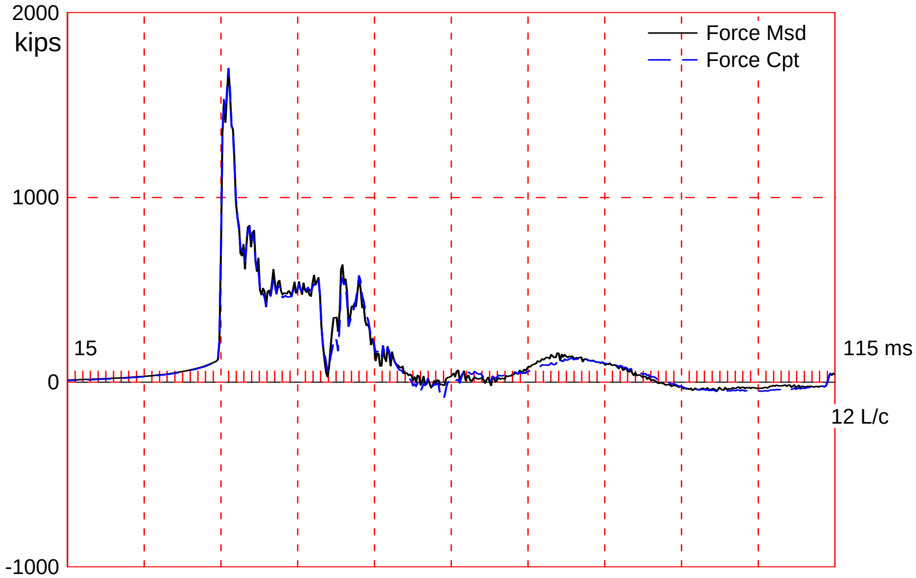
PILE PROFILE AND PILE MODEL

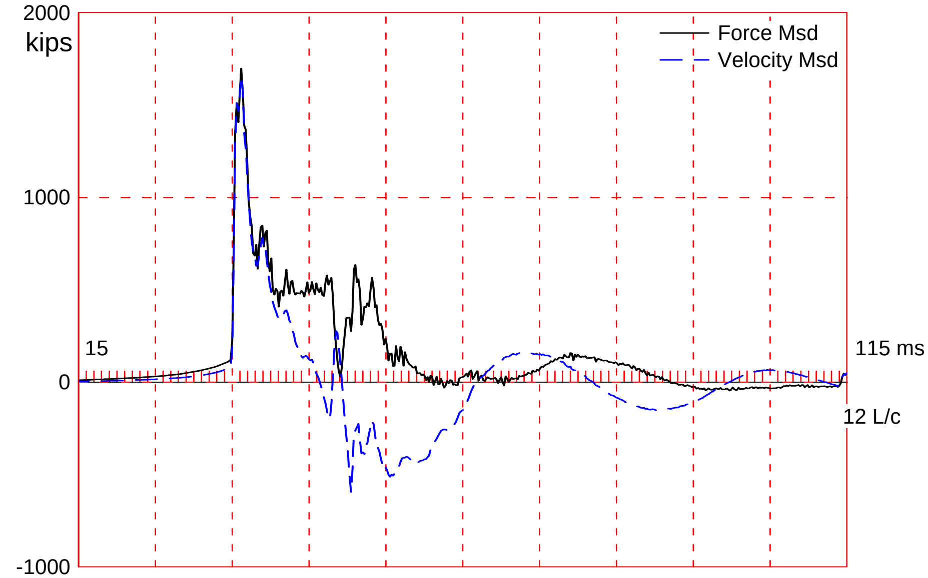
Depth ft	Area in^2	E-Modulus ksi	Spec. Weight lb/ft^3	Perim. ft
0.0	57.7	30000.0	492.000	7.85
55.0	57.7	30000.0	492.000	7.85

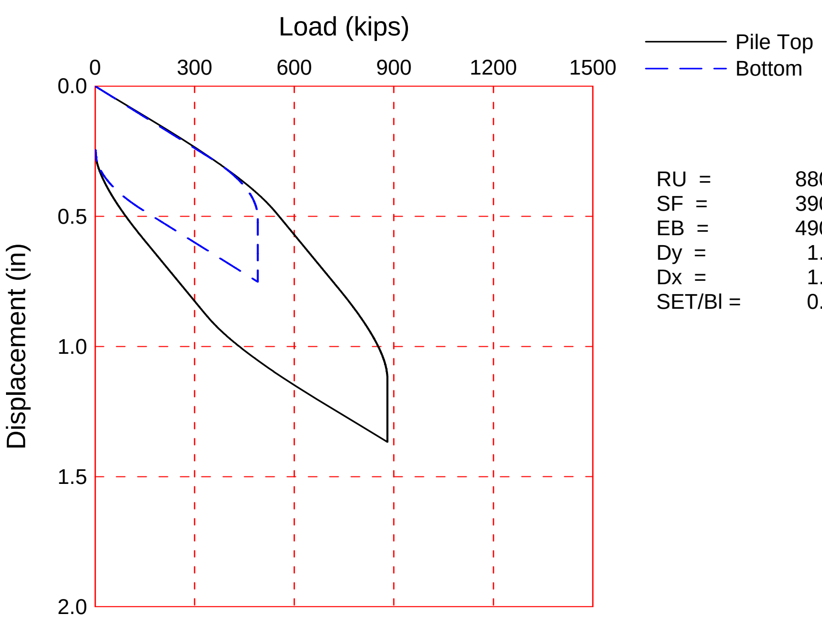
Toe Area 57.7 in^2

Top Segment Length 3.44 ft, Top Impedance 103 kips/ft/s

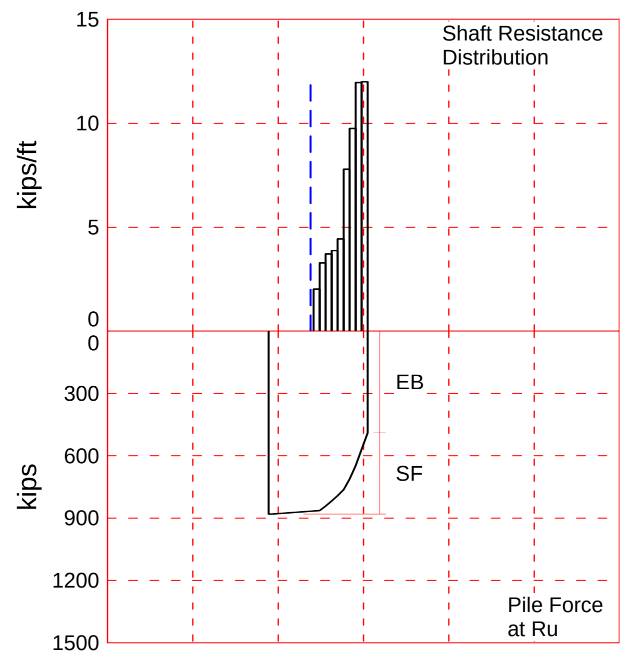
Wave Speed: Pile Top 16807.9, Elastic 16807.9, Overall 16901.4 ft/s
Pile Damping 1.00 %, Time Incr 0.203 ms, 2L/c 6.5 ms
Total volume: 22.030 ft^3; Volume ratio considering added impedance: 1.000







RU = 880.6 kips
SF = 390.4 kips
EB = 490.2 kips
Dy = 1.12 in
Dx = 1.37 in
SET/Bl = 0.24 in



Length b. Sensors	108.5 ft
Embedment	61.0 ft
Top Area	57.7 in^2
End Bearing Area	57.7 in^2
Top Perimeter	7.85 ft
Top E-Modulus	30000 ksi
Top Spec. Weight	492.0 lb/ft^3
Top Wave Spd.	16808 ft/s
Overall W.S.	16813 ft/s
Match Quality	2.60
Top Compr. Stress	29.4 ksi
Max Compr. Stress	30.5 ksi
Max Tension Stress	-3.43 ksi
Avg. Shaft Quake	0.10 in
Toe Quake	0.39 in
Avg. Shaft Smith Dpg.	0.22 s/ft
Toe Smith Damping	0.05 s/ft

CAPWAP SUMMARY RESULTS

Total CAPWAP Capacity: 880.6; along Shaft 390.4; at Toe 490.2 kips

Soil Sgmnt No.	Dist. Below Gages ft	Depth Below Grade ft	Ru kips	Force in Pile kips	Sum of Ru kips	Unit Resist. (Depth) kips/ft	Unit Resist. (Area) ksf
				880.6			
1	55.9	8.4	16.9	863.7	16.9	2.02	0.26
2	62.5	14.9	21.6	842.1	38.5	3.28	0.42
3	69.0	21.5	24.4	817.7	62.9	3.71	0.47
4	75.6	28.1	25.5	792.2	88.4	3.88	0.49
5	82.2	34.7	29.2	763.0	117.6	4.44	0.57
6	88.8	41.2	51.2	711.8	168.8	7.79	0.99
7	95.3	47.8	64.1	647.7	232.9	9.75	1.24
8	101.9	54.4	78.6	569.1	311.5	11.95	1.52
9	108.5	61.0	78.9	490.2	390.4	12.00	1.53
Avg. Shaft			43.4			6.40	0.82
Toe			490.2				1223.97

Soil Model Parameters/Extensions		Shaft	Toe
Smith Damping Factor		0.22	0.05
Quake	(in)	0.10	0.39
Case Damping Factor		0.83	0.24
Damping Type		Viscous	Sm+Visc
Unloading Quake	(% of loading quake)	60	80
Reloading Level	(% of Ru)	100	100

CAPWAP match quality = 2.60 (Wave Up Match) ; RSA = 0
Observed: Final Set = 0.24 in; Blow Count = 49 b/ft
Computed: Final Set = 0.24 in; Blow Count = 50 b/ft
Transducer F2 (H895) CAL: 91.3; RF: 1.00; F3 (V884) CAL: 91.9; RF: 1.00
A1 (K5182) CAL: 345; RF: 1.00; A4 (K3260) CAL: 357; RF: 1.00

max. Top Comp. Stress = 29.4 ksi (T= 36.4 ms, max= 1.037 x Top)
max. Comp. Stress = 30.5 ksi (Z= 55.9 ft, T= 39.5 ms)
max. Tens. Stress = -3.43 ksi (Z= 49.3 ft, T= 63.2 ms)
max. Energy (EMX) = 60.5 kip-ft; max. Measured Top Displ. (DMX)= 0.80 in

EXTREMA TABLE

Pile Sgmnt No.	Dist. Below Gages ft	max. Force kips	min. Force kips	max. Comp. Stress ksi	max. Tens. Stress ksi	max. Trnsfd. Energy kip-ft	max. Veloc. ft/s	max. Displ. in
1	3.3	1697.2	-98.8	29.4	-1.71	60.5	16.1	0.81
2	6.6	1696.9	-102.6	29.4	-1.78	60.2	16.1	0.80
4	13.2	1696.8	-117.4	29.4	-2.04	59.8	16.0	0.79
6	19.7	1696.8	-125.3	29.4	-2.17	59.4	16.0	0.77
8	26.3	1697.1	-148.8	29.4	-2.58	59.1	15.9	0.75
10	32.9	1697.9	-176.3	29.4	-3.06	58.6	15.9	0.73
12	39.5	1699.4	-164.2	29.5	-2.85	57.9	15.8	0.70
14	46.0	1702.6	-195.2	29.5	-3.38	57.1	15.7	0.67
16	52.6	1733.2	-188.5	30.0	-3.27	56.3	15.4	0.64
18	59.2	1701.4	-164.7	29.5	-2.86	53.1	15.0	0.61
20	65.8	1655.7	-148.2	28.7	-2.57	49.4	14.5	0.58
22	72.3	1602.7	-141.9	27.8	-2.46	45.5	14.0	0.55
24	78.9	1553.6	-134.8	26.9	-2.34	41.8	13.4	0.52
25	82.2	1606.7	-137.9	27.9	-2.39	41.3	12.9	0.50
26	85.5	1521.4	-102.3	26.4	-1.77	37.7	12.6	0.49
27	88.8	1586.4	-102.4	27.5	-1.78	37.2	12.0	0.47
28	92.1	1432.2	-40.9	24.8	-0.71	31.9	11.7	0.46
29	95.3	1505.8	-41.9	26.1	-0.73	31.4	11.2	0.44
30	98.6	1285.3	-0.1	22.3	-0.00	25.3	13.1	0.43
31	101.9	1182.5	-0.1	20.5	-0.00	24.9	15.2	0.41
32	105.2	762.1	-0.1	13.2	-0.00	17.4	15.0	0.40
33	108.5	689.0	-0.0	11.9	-0.00	10.7	14.9	0.39
Absolute	55.9			30.5			(T =	39.5 ms)
	49.3				-3.43		(T =	63.2 ms)

CASE METHOD

J =	0.0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8
RP	1716.2	1358.8	1001.4	643.9	286.5					
RX	1716.2	1387.5	1184.4	1089.7	1006.1	943.0	892.8	842.6	795.2	792.2
RU	1737.1	1383.8	1030.6	677.3	324.1					

RAU = 716.3 (kips); RA2 = 1009.3 (kips)

Current CAPWAP Ru = 880.6 (kips); Corresponding J(RP)= 0.47; J(RX) = 1.25

VMX ft/s	TVP ms	VT1*Z kips	FT1 kips	FMX kips	DMX in	DFN in	SET in	EMX kip-ft	QUS kips	KEB kips/in
16.8	36.18	1733.0	1770.4	1770.4	0.80	0.22	0.24	60.9	1405.7	1257

PILE PROFILE AND PILE MODEL

Depth ft	Area in^2	E-Modulus ksi	Spec. Weight lb/ft^3	Perim. ft
0.0	57.7	30000.0	492.000	7.85
108.5	57.7	30000.0	492.000	7.85

Toe Area 57.7 in^2

Top Segment Length 3.29 ft, Top Impedance 103 kips/ft/s

Wave Speed: Pile Top 16807.9, Elastic 16807.9, Overall 16813.3 ft/s
Pile Damping 1.00 %, Time Incr 0.196 ms, 2L/c 12.9 ms

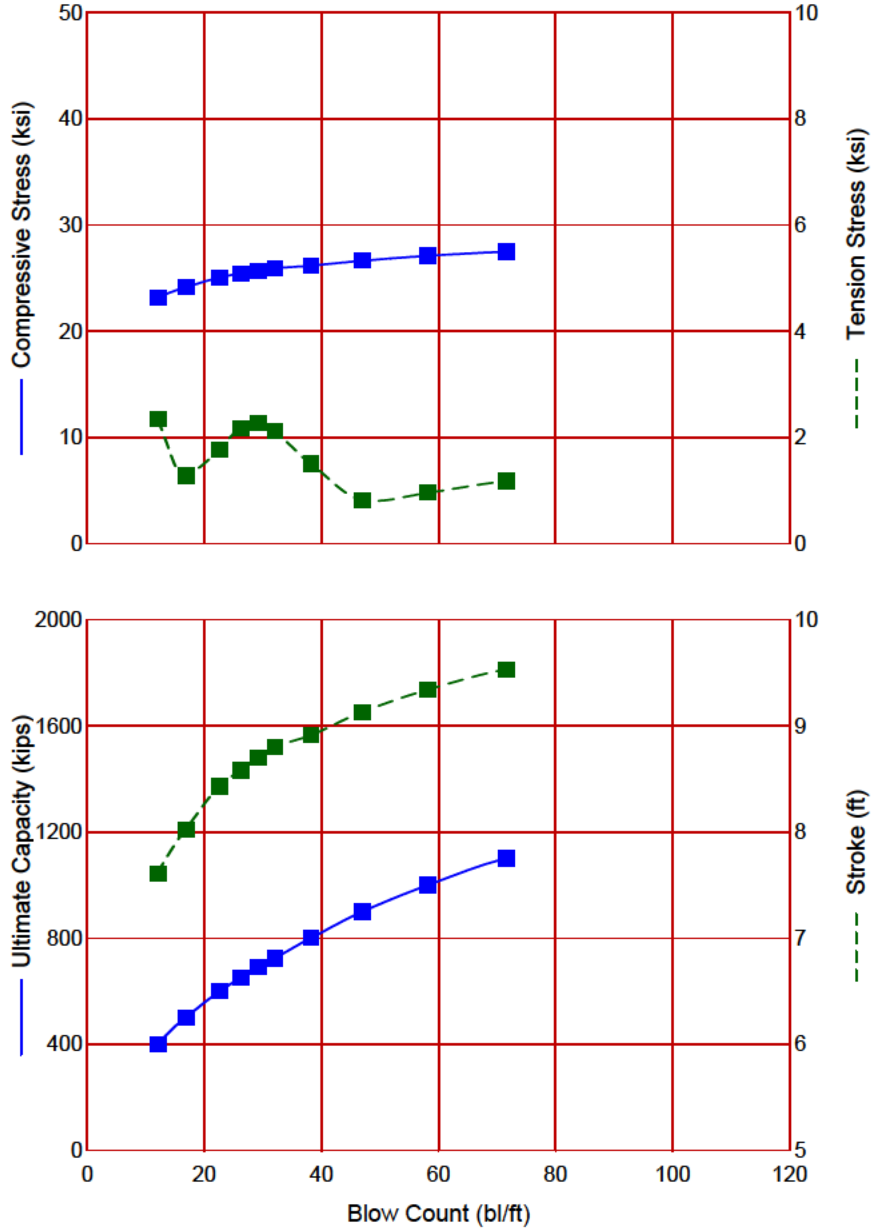
Total volume: 43.459 ft³; Volume ratio considering added impedance: 1.000

Appendix D

Wave Equation Bearing Graph Analysis for the Test Pile

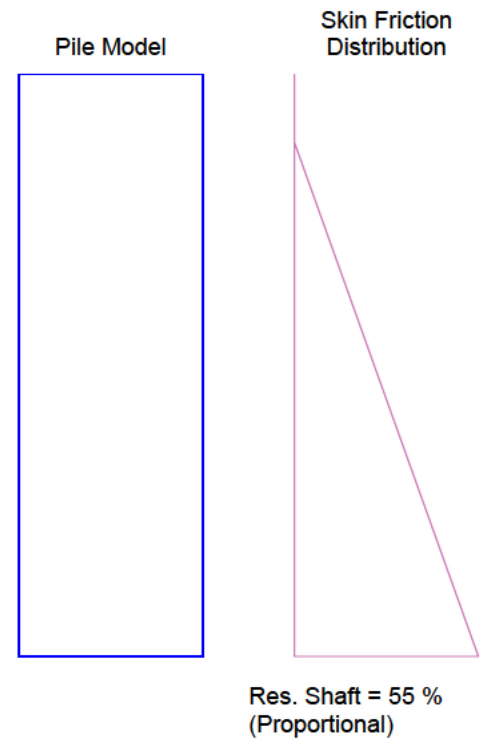
Robert Miner Dynamic Testing, Inc.
FLJV, Br25E Pier 2, D50 Match

06-Jan-2022
GRLWEAP Version 2010



APE D 50-52

Ram Weight	11.03	kips
Efficiency	0.720	
Pressure	1717 (108%)	psi
Helmet Weight	5.40	kips
Hammer Cushion	40000	kips/in
COR of H.C.	0.800	
Skin Quake	0.100	in
Toe Quake	0.350	in
Skin Damping	0.070	s/ft
Toe Damping	0.090	s/ft
Pile Length	60.00	ft
Pile Penetration	53.00	ft
Pile Top Area	57.67	in2

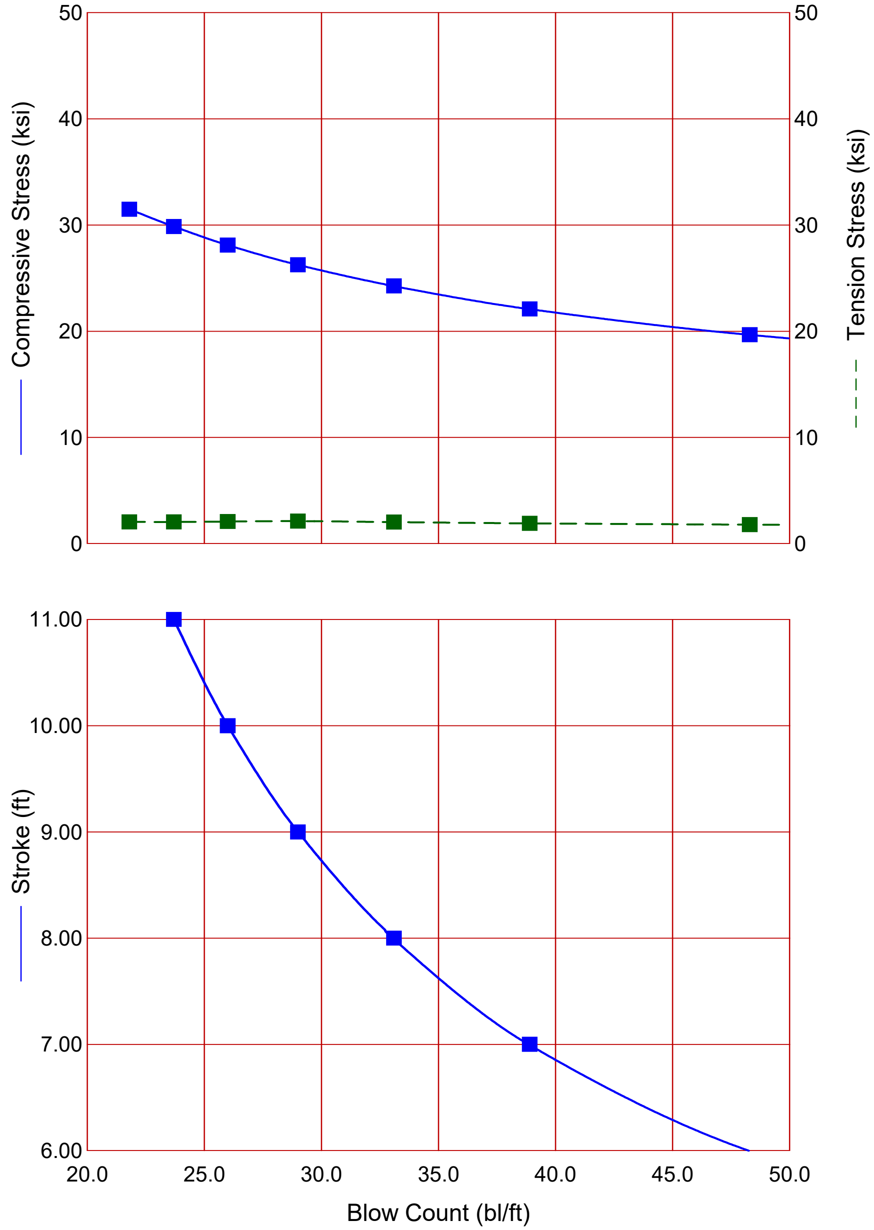


Robert Miner Dynamic Testing, Inc. 06-Jan-2022
FLJV, Br25E Pier 2, D50 Match GRLWEAP Version 2010

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count bl/ft	Stroke ft	Energy kips-ft
400.0	23.16	2.34	12.2	7.61	58.33
500.0	24.13	1.28	16.9	8.02	56.41
600.0	25.06	1.78	22.7	8.43	55.56
650.0	25.44	2.17	26.2	8.58	55.31
690.0	25.67	2.27	29.3	8.70	55.02
724.0	25.91	2.12	32.1	8.80	54.92
800.0	26.18	1.51	38.2	8.91	53.91
900.0	26.63	0.82	47.0	9.13	53.23
1000.0	27.10	0.96	58.2	9.34	53.69
1100.0	27.48	1.18	71.6	9.53	54.39

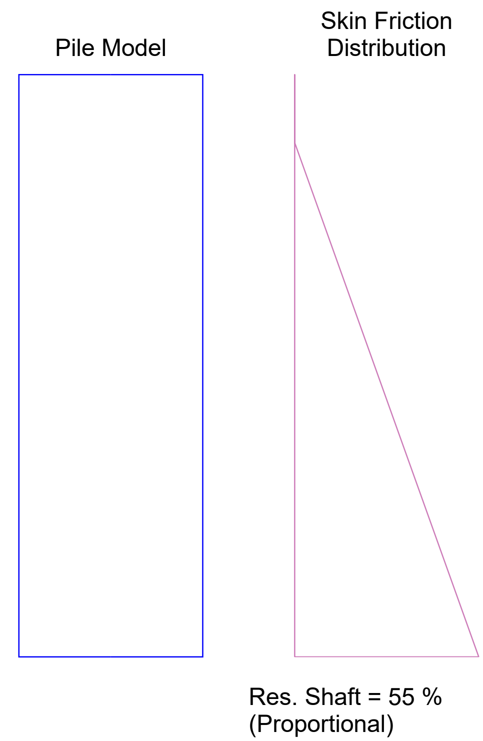
Appendix E

Wave Equation Inspector's Chart Analysis



APE D 50-52

Capacity	682.0	kips
Ram Weight	11.03	kips
Efficiency	0.720	
Pressure	1717 (108%)	psi
Helmet Weight	5.40	kips
Hammer Cushion	40000	kips/in
COR of H.C.	0.800	
Skin Quake	0.100	in
Toe Quake	0.350	in
Skin Damping	0.080	s/ft
Toe Damping	0.090	s/ft
Pile Length	60.00	ft
Pile Penetration	53.00	ft
Pile Top Area	57.67	in2



Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count bl/ft	Stroke ft	Energy kips-ft
682.0	10.61	1.23	306.2	3.00	13.73
682.0	13.65	1.52	98.3	4.00	21.98
682.0	16.91	1.59	64.3	5.00	29.45
682.0	19.67	1.79	48.3	6.00	36.65
682.0	22.09	1.92	38.9	7.00	43.49
682.0	24.26	2.04	33.1	8.00	50.12
682.0	26.25	2.13	29.0	9.00	56.61
682.0	28.11	2.09	26.0	10.00	62.91
682.0	29.86	2.05	23.7	11.00	69.22
682.0	31.48	2.05	21.8	12.00	75.37

Appendix F

Dynamic Measurements Addressing
Standard Specification 6-05.3(9)C, Pile Driving Leads

On December 22, 2021 RMDT collected high strain dynamic pile measurements as production pile Pile 25E-2C was impact driven with an APE D50-42 hammer operating in swinging leads. This work was completed in conjunction with RMDT's work on the Test Pile in location 25E-2E. The general project information and information on our methods which is given in our report for the Test Pile applies to our work on production pile 25E-2C. Our work on Production Pile 25E-2C presented in Appendix F was completed to satisfy Section 6-05.3(9)C of the State Standard Specification. This section includes the following statement:

"Pile driving leads other than those fixed at the top and bottom may be used to complete driving, if permitted by the Engineer, when all of the following criteria are met:

1. *Each plumb and battered pile is located and initially driven at least 20 feet in true alignment using fixed leads or other approved means.*
2. *The pile driving system (hammer, cushion and pile) will be analyzed by Pile Driving Analyzer (PDA) to verify driving stresses in the pile are not increased due to eccentric loading during driving, and transferred hammer energy is not reduced due to eccentric loading during driving, for all test piles and at least one production pile per pier. Unless otherwise specified, the cost of PDA testing shall be incidental to the various unit Contract prices for driving piles."*

Our presentation of measurements on Pile 25E-2C pertains only to the use of a Pile Driving Analyzer for item 2 above. Field Case Method results for Production Pile 25E-2C are given in graphic and numeric formats on following pages versus depth, with values averaged over 1 ft intervals of driving, similar to the format of the Test Pile results in Appendix B. Additionally a numeric summary of individual blows is given for the last 3 ft of driving on Pile 25E-2C and 25E-2E. Comparison of the CSX and CSI values for individual hammer blows provides an indication of the uniformity of the driving stresses across the pile section. For example, if the CSX and CSI values are very similar, then the impact stresses are likely to be relatively uniform across the pile section. (Because the standard configuration includes two sensors, the results may only indicate uniformity relative to one possible axis.) If the CSX and CSI vales are not similar, then some degree of eccentricity or misalignment of the hammer and pile top is probably occurring. For the two monitored piles the differences between CSX and CSI were typically between 3 and 5 ksi; such values are within commonly observed acceptable ranges given the levels of CSX relative to the nominal material yeild strength.

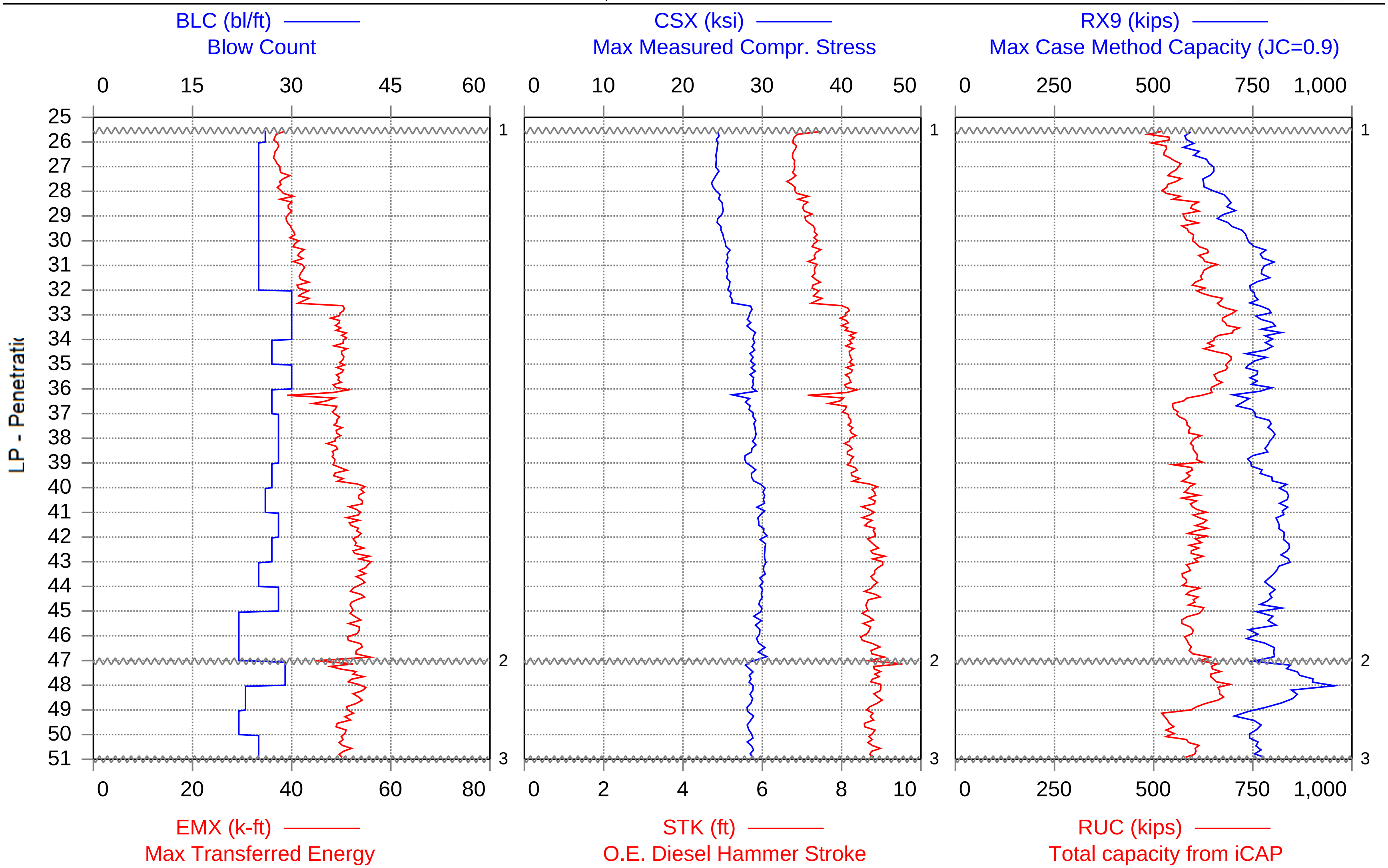
The measured value of energy transferred from the hammer to the pile at the sensor location, EMX, is also given in the results presented in Appendix G. Thus, the results may be used to evaluate if energy transfer varies significantly when the relation of CSI to CSX varies. For example, if EMX values decrease noticeably when CSX and CSI values are very different this would be evidence that nonuniform impact was reducing the efficiency of energy transfer from the hammer to the pile.

Inspection of the results for Pile 25E-2C and 25E suggests that at the end of initial driving differences between CSX and CSI from blow to blow were not correlated with significant variation of transfer energy, EMX. The EMX values near the end of driving indicate that there was relatively constant energy transfer as the relation of CSX to CSI changed.

Notwithstanding the relation between stress uniformity and EMX, there was naturally modest variation of EMX as the ram stroke height varied. While such variation may be relevant when comparing different piles and times of driving for other purposes, investigation of this source of variation not an objective of our data review under the requirements of Section 6-05.3(9)C.

Based on the available data, it is our opinion that result for the Test Pile and Production Pile 25E-2C both support a finding that variations in stress uniformity near the pile top were not accompanied by significant variations of the transfer efficiency or excessive driving stress with the D50-42 and the leads in use.

Robert Miner Dynamic Testing, Inc. - PDIPLOT2 Ver 2021.1.61.0 - Case Method & iCAP® Results
Printed: 23-December-2021 Test started: 22-December-2021
Flatiron-Lane JV, 25ENB - 25E-2C



1 - Start of test on 12/22/2021 at 11:10 PM
2 - Restart after 4 minutes 49 seconds
3 - End of test on 12/22/2021 at 11:30 PM

Case Method & iCAP® Results

Flatiron-Lane JV, 25ENB - 25E-2C PP30"x0.625", APE D50-52

OP: RMDT Date: 22-December-2021

AR:	57.68	in^2	SP:	0.492	k/ft^3
LE:	54.50	ft	EM:	30,000	ksi
WS:	16,807.9	f/s	JC:	0.90	

CSI: Max F1 or F2 Compr. Stress
CSX: Max Measured Compr. Stress
STK: O.E. Diesel Hammer Stroke
EMX: Max Transferred Energy
BPM: Blows per Minute
FMX: Maximum Force
VMX: Maximum Velocity
RX9: Max Case Method Capacity (JC=0.9)
RUC: Total capacity from iCAP

BL#	Depth	BLC	TYPE	CSI	CSX	STK	EMX	BPM	FMX	VMX	RX9	RUC
	ft	bl/ft		ksi	ksi	ft	k-ft	bpm	kips	f/s	kips	kips
13	26.0	26	AV13	29.8	24.4	6.98	37.1	44.6	1,407	12.4	588	521
			STD	2.3	0.7	0.32	1.4	0.9	38	0.3	13	37
			MAX	36.4	25.7	7.70	39.7	45.8	1,480	12.7	622	561
			MIN	27.4	22.7	6.61	34.9	42.5	1,308	11.6	567	426
38	27.0	25	AV25	28.4	24.2	6.80	37.0	45.1	1,399	12.4	613	537
			STD	0.6	0.3	0.09	1.1	0.3	16	0.2	29	24
			MAX	30.2	24.8	7.01	39.7	45.6	1,429	12.9	675	570
			MIN	27.4	23.7	6.67	35.3	44.5	1,369	12.1	548	469
63	28.0	25	AV25	26.9	24.0	6.77	37.9	45.3	1,383	12.9	638	545
			STD	1.5	0.5	0.13	1.5	0.4	28	0.4	24	16
			MAX	31.2	24.7	7.14	40.3	46.0	1,425	13.7	678	575
			MIN	24.9	22.7	6.53	35.2	44.1	1,309	12.2	591	511
88	29.0	25	AV25	26.5	24.8	7.06	39.4	44.4	1,432	13.7	686	580
			STD	1.2	0.5	0.18	1.4	0.5	29	0.4	29	28
			MAX	31.3	26.0	7.65	42.0	45.2	1,497	14.4	732	616
			MIN	25.4	23.7	6.79	36.9	42.7	1,365	12.6	618	526
113	30.0	25	AV25	29.4	24.8	7.26	39.8	43.8	1,429	13.7	708	589
			STD	0.8	0.8	0.24	2.2	0.7	44	0.5	36	17
			MAX	30.8	26.2	7.61	43.8	45.5	1,509	14.7	759	626
			MIN	27.3	23.3	6.71	35.5	42.8	1,345	12.8	616	556

Case Method & iCAP® Results

Flatiron-Lane JV, 25ENB - 25E-2C PP30"x0.625", APE D50-52
OP: RMDT Date: 22-December-2021

BL#	Depth	BLC	TYPE	CSI	CSX	STK	EMX	BPM	FMX	VMX	RX9	RUC
	ft	bl/ft		ksi	ksi	ft	k-ft	bpm	kips	f/s	kips	kips
138	31.0	25	AV25	28.3	25.5	7.32	41.3	43.6	1,474	14.1	769	628
			STD	0.9	0.4	0.14	1.3	0.4	21	0.3	29	20
			MAX	30.1	26.2	7.57	43.3	44.5	1,508	14.6	836	661
			MIN	26.2	24.8	7.01	38.6	42.9	1,431	13.6	723	595
163	32.0	25	AV25	27.6	25.7	7.32	42.0	43.6	1,481	14.4	768	620
			STD	0.4	0.3	0.11	1.1	0.3	18	0.3	27	20
			MAX	28.3	26.4	7.53	44.4	44.3	1,523	15.1	816	666
			MIN	26.6	25.2	7.08	39.3	43.0	1,451	13.9	723	585
193	33.0	30	AV30	29.3	27.1	7.68	45.7	42.6	1,565	15.1	767	666
			STD	2.2	1.4	0.44	4.4	1.1	80	0.7	26	31
			MAX	32.9	29.6	8.44	54.3	44.2	1,708	16.4	822	714
			MIN	26.4	25.4	7.12	39.7	40.7	1,466	13.9	719	586
223	34.0	30	AV30	32.2	28.5	8.15	49.6	41.4	1,647	15.5	789	682
			STD	1.0	0.5	0.16	1.5	0.4	27	0.3	35	20
			MAX	34.2	29.5	8.47	51.9	42.6	1,700	16.0	858	731
			MIN	30.2	27.2	7.69	45.8	40.6	1,566	14.9	744	641
250	35.0	27	AV27	33.2	28.8	8.23	50.2	41.2	1,660	15.5	773	665
			STD	0.6	0.5	0.15	1.5	0.4	27	0.3	32	27
			MAX	34.4	29.6	8.52	52.8	42.0	1,709	16.0	850	701
			MIN	31.7	27.7	7.90	46.7	40.5	1,595	14.9	711	621
280	36.0	30	AV30	33.6	28.8	8.18	49.5	41.3	1,661	15.3	755	665
			STD	0.8	0.5	0.15	1.3	0.4	29	0.3	29	14
			MAX	35.2	29.7	8.50	52.3	42.3	1,713	15.9	831	694
			MIN	32.1	27.5	7.80	46.5	40.6	1,586	14.6	685	641
307	37.0	27	AV27	33.0	28.2	7.96	47.3	41.9	1,627	15.1	733	582
			STD	1.5	1.2	0.39	3.8	1.0	70	0.7	39	39

Case Method & iCAP® Results

Flatiron-Lane JV, 25ENB - 25E-2C PP30"x0.625", APE D50-52
OP: RMDT Date: 22-December-2021

BL#	Depth	BLC	TYPE	CSI	CSX	STK	EMX	BPM	FMX	VMX	RX9	RUC
	ft	bl/ft		ksi	ksi	ft	k-ft	bpm	kips	f/s	kips	kips
			MAX	35.6	30.0	8.53	53.1	44.7	1,729	16.2	809	652
			MIN	29.5	25.2	6.95	36.7	40.5	1,453	13.4	652	526
335	38.0	28	AV28	34.2	29.0	8.22	49.1	41.2	1,673	15.4	789	589
			STD	0.7	0.5	0.18	1.4	0.4	30	0.3	26	17
			MAX	35.3	29.7	8.49	52.0	42.6	1,715	16.0	837	640
			MIN	32.5	27.6	7.69	46.0	40.6	1,589	14.6	733	549
363	39.0	28	AV28	33.2	28.5	8.20	48.5	41.3	1,643	15.2	771	604
			STD	1.9	0.7	0.19	1.7	0.5	39	0.4	36	12
			MAX	36.0	29.8	8.59	51.9	42.4	1,721	15.9	834	624
			MIN	29.4	27.0	7.76	44.8	40.4	1,559	14.2	703	583
390	40.0	27	AV27	34.5	29.0	8.41	50.5	40.8	1,673	15.4	788	585
			STD	1.1	0.8	0.27	2.6	0.6	46	0.5	35	19
			MAX	36.7	30.7	8.98	55.1	42.3	1,773	16.3	855	621
			MIN	32.4	27.4	7.79	44.3	39.5	1,578	14.1	720	535
416	41.0	26	AV26	35.8	30.1	8.77	53.7	40.0	1,734	15.9	831	598
			STD	0.7	0.5	0.18	1.5	0.4	29	0.3	20	22
			MAX	37.1	30.8	9.04	55.9	41.1	1,775	16.3	864	659
			MIN	33.3	28.6	8.27	50.1	39.4	1,651	15.1	800	556
444	42.0	28	AV28	35.8	29.9	8.72	52.8	40.1	1,724	15.8	820	616
			STD	1.2	0.9	0.31	2.5	0.7	50	0.5	27	21
			MAX	37.7	31.1	9.18	56.3	42.2	1,792	16.6	868	659
			MIN	32.9	27.6	7.83	45.2	39.1	1,590	14.5	763	557
471	43.0	27	AV26	36.2	30.2	8.83	53.6	39.8	1,744	15.9	836	606
			STD	0.9	0.7	0.24	2.1	0.5	43	0.5	28	18
			MAX	37.7	31.3	9.19	56.9	41.4	1,808	16.6	887	650
			MIN	33.5	28.0	8.13	47.1	39.1	1,614	14.6	784	565

Case Method & iCAP® Results

Flatiron-Lane JV, 25ENB - 25E-2C PP30"x0.625", APE D50-52
OP: RMDT Date: 22-December-2021

BL#	Depth	BLC	TYPE	CSI	CSX	STK	EMX	BPM	FMX	VMX	RX9	RUC
	ft	bl/ft		ksi	ksi	ft	k-ft	bpm	kips	f/s	kips	kips
496	44.0	25	AV25	35.9	30.1	8.87	54.4	39.7	1,736	15.9	803	582
			STD	0.7	0.5	0.21	1.9	0.4	31	0.4	19	19
			MAX	37.2	31.0	9.26	58.1	40.5	1,787	16.6	844	618
			MIN	34.5	29.1	8.52	51.5	38.9	1,681	15.1	766	550
524	45.0	28	AV27	35.8	29.8	8.71	52.7	40.1	1,717	15.7	795	604
			STD	0.7	0.7	0.28	2.3	0.6	39	0.4	30	26
			MAX	37.3	30.7	9.03	55.8	41.4	1,771	16.3	851	665
			MIN	34.5	28.5	8.16	48.3	39.4	1,643	14.9	730	554
546	46.0	22	AV22	35.4	29.5	8.66	52.9	40.2	1,703	15.6	775	590
			STD	0.9	0.8	0.26	2.3	0.6	45	0.5	49	18
			MAX	37.0	30.7	8.98	55.6	42.2	1,769	16.3	848	623
			MIN	32.9	27.4	7.83	46.0	39.5	1,581	14.4	701	559
568	47.0	22	AV22	35.5	29.7	8.71	52.2	40.1	1,711	15.6	780	599
			STD	1.7	1.1	0.39	4.5	0.9	66	0.7	43	23
			MAX	37.4	31.2	9.18	56.4	43.2	1,797	16.5	836	644
			MIN	29.0	25.9	7.44	34.8	39.1	1,494	13.5	667	557
597	48.0	29	AV28	32.3	28.5	8.97	51.8	39.5	1,642	15.6	869	655
			STD	3.0	0.8	0.33	2.7	0.7	48	0.5	60	24
			MAX	39.3	30.5	9.92	57.1	40.5	1,757	16.5	992	706
			MIN	29.2	25.4	8.51	45.4	37.6	1,463	14.5	710	616
620	49.0	23	AV23	30.4	28.5	8.88	53.1	39.7	1,646	16.0	841	648
			STD	0.9	0.4	0.16	1.6	0.4	25	0.5	48	28
			MAX	33.5	29.2	9.20	55.7	40.6	1,684	17.3	987	682
			MIN	29.2	27.5	8.50	49.7	39.0	1,588	14.9	761	592
642	50.0	22	AV22	32.9	28.5	8.73	50.8	40.1	1,643	15.2	744	539
			STD	1.5	0.6	0.17	1.7	0.4	36	0.5	34	22
			MAX	36.2	29.5	9.02	53.0	41.1	1,703	16.2	808	591

Case Method & iCAP® Results

Flatiron-Lane JV, 25ENB - 25E-2C PP30"x0.625", APE D50-52
OP: RMDT Date: 22-December-2021

BL#	Depth	BLC	TYPE	CSI	CSX	STK	EMX	BPM	FMX	VMX	RX9	RUC
	ft	bl/ft		ksi	ksi	ft	k-ft	bpm	kips	f/s	kips	kips
			MIN	29.6	26.9	8.29	46.1	39.4	1,549	14.3	664	504
667	51.0	25	AV24	32.2	28.6	8.77	50.3	40.0	1,649	15.5	759	589
			STD	0.8	0.6	0.18	1.5	0.4	33	0.3	22	28
			MAX	33.9	29.9	9.13	53.4	40.6	1,724	16.1	788	633
			MIN	30.6	27.5	8.49	47.7	39.2	1,584	14.8	717	508

BL#	Sensors
1-568	F2: [H895] 91.3 (1.00); F3: [M095] 151.8 (1.00); A1: [K5182] 345.0 (1.00); A4: [K3260] 357.0 (1.00)
570-666	F2: [H895] 91.3 (1.00); F3: [V884] 91.9 (1.00); A1: [K5182] 345.0 (1.00); A4: [K3260] 357.0 (1.00)

BL#	Comments
1	Start of test on 12/22/2021 at 11:10 PM
569	Restart after 4 minutes 49 seconds
667	End of test on 12/22/2021 at 11:30 PM

Time Summary

Drive 13 minutes 34 seconds 11:10 PM - 11:23 PM (12/22/2021) BN 1 - 568
Stop 4 minutes 49 seconds 11:23 PM - 11:28 PM
Drive 2 minutes 27 seconds 11:28 PM - 11:30 PM BN 569 - 667

Total time [00:20:52] = (Driving [00:16:02] + Stop [00:04:49])

Case Method & iCAP® Results

Flatiron-Lane JV, 25ENB - 25E-2C PP30"x0.625", APE D50-52
OP: RMDT Date: 22-December-2021

AR: 57.68 in² SP: 0.492 k/ft³
LE: 54.50 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.90

CSI: Comp Stress Max-Individual Sens
CSX: Compression Stress Maximum
EMX: Maximum Energy
STK: Hammer Stroke
BPM: Blows/Minute
FMX: Maximum Force
VMX: Maximum Velocity
RX7: Maximum Case Method Capacity (JC=0.7)
RUC: Total capacity from iCAP

BL#	BLC	CSI	CSX	EMX	STK	BPM	FMX	VMX	RX7	RUC
	bl/in	ksi	ksi	k-ft	ft	bpm	kips	f/s	kips	kips
597	2	30.0	28.7	53.1	8.96	39.5	1,658	15.5	994	701
598	2	30.0	29.0	54.1	8.94	39.6	1,670	16.3	993	652
599	2	30.6	29.1	55.7	9.03	39.4	1,677	16.2	924	668
600	2	30.0	29.0	55.1	8.99	39.5	1,671	16.2	827	666
601	2	29.8	28.5	53.3	8.85	39.8	1,641	15.5	881	657
602	2	30.5	28.9	54.4	8.99	39.5	1,666	16.4	843	671
603	2	30.7	28.9	55.1	9.10	39.3	1,665	16.0	852	671
604	2	30.8	28.8	54.1	8.97	39.5	1,663	16.2	839	674
605	2	29.5	28.3	51.5	8.84	39.8	1,635	15.8	883	663
606	2	29.2	28.0	51.6	8.62	40.3	1,614	16.4	909	661
607	2	29.9	28.6	53.4	8.91	39.7	1,651	15.6	844	682
608	2	29.9	28.3	53.1	8.82	39.8	1,631	16.1	842	674
609	2	29.8	28.7	54.0	9.00	39.5	1,657	15.9	847	675
610	2	30.8	29.2	55.5	9.20	39.0	1,684	17.3	880	674
611	2	30.1	28.9	52.9	8.91	39.6	1,664	15.8	833	659
612	2	30.1	28.6	54.2	8.96	39.6	1,647	16.4	852	652
613	2	30.1	28.6	53.0	8.85	39.8	1,649	16.0	849	629
614	2	33.5	28.9	54.1	9.02	39.4	1,669	16.1	815	640
615	2	31.6	28.3	51.8	8.78	39.9	1,630	15.9	792	623
616	2	29.5	27.7	49.8	8.57	40.4	1,598	14.9	811	626
617	2	31.9	28.2	52.3	8.82	39.8	1,628	15.5	765	594
618	2	31.3	28.1	51.2	8.75	40.0	1,623	15.6	802	606
619	2	30.2	28.2	52.2	8.71	40.1	1,629	15.8	763	600
620	2	30.3	27.5	49.7	8.50	40.6	1,588	15.1	789	592
621	2	31.0	28.3	52.0	8.67	40.2	1,632	16.2	703	591
622	2	29.6	27.6	52.0	8.52	40.5	1,592	15.8	729	545
623	2	35.2	29.2	53.0	8.83	39.8	1,683	15.1	739	504
624	2	36.2	29.5	52.4	9.02	39.4	1,703	14.9	726	510
625	2	32.1	28.4	52.0	8.86	39.8	1,637	15.3	688	510
626	2	33.7	29.1	51.1	8.75	40.0	1,678	15.4	729	519
627	2	35.5	28.6	49.1	8.56	40.4	1,650	14.3	735	554
628	2	32.3	28.8	51.9	8.83	39.8	1,660	15.7	734	542
629	2	33.1	29.1	52.9	8.83	39.8	1,677	15.4	781	533
630	2	34.4	28.7	50.7	8.77	40.0	1,656	14.9	786	529
631	2	31.8	27.4	47.1	8.40	40.8	1,583	14.5	724	573
632	2	31.4	27.8	50.6	8.69	40.1	1,604	15.4	778	520
633	2	33.2	28.1	49.9	8.63	40.3	1,619	14.9	766	525
634	2	32.9	28.3	50.9	8.77	39.9	1,631	15.2	801	524
635	2	31.6	28.2	49.8	8.67	40.2	1,627	15.6	760	557
636	2	31.4	26.9	46.1	8.29	41.1	1,549	14.3	739	571
637	2	33.5	28.8	50.6	8.85	39.8	1,660	15.0	808	527
638	2	32.2	28.7	51.5	8.90	39.7	1,654	15.7	773	546
639	2	33.3	28.8	50.9	8.78	39.9	1,664	15.2	761	520
640	2	33.4	28.7	49.4	8.63	40.3	1,653	14.8	741	549
641	2	32.8	28.7	50.5	8.70	40.1	1,656	14.9	774	566

Case Method & iCAP® Results

Flatiron-Lane JV, 25ENB - 25E-2C PP30"x0.625", APE D50-52
OP: RMDT Date: 22-December-2021

BL#	BLC	CSI	CSX	EMX	STK	BPM	FMX	VMX	RX7	RUC
	bl/in	ksi	ksi	k-ft	ft	bpm	kips	f/s	kips	kips
642	2	33.0	29.0	52.3	9.02	39.4	1,674	15.6	769	539
643	2	32.9	28.2	49.8	8.72	40.1	1,624	15.0	740	534
644	2	31.8	28.3	48.8	8.52	40.5	1,632	15.2	764	551
645	2	33.3	29.0	51.4	8.83	39.8	1,675	15.4	747	508
646	2	33.2	29.0	52.9	9.08	39.3	1,671	15.8	771	572
647	2	32.9	29.0	50.3	8.70	40.1	1,673	15.2	776	590
648	2	30.6	27.5	47.9	8.53	40.5	1,584	15.2	770	586
649	2	31.9	28.1	47.7	8.49	40.6	1,623	14.8	780	589
650	2	31.7	27.7	49.5	8.57	40.4	1,599	15.0	786	567
651	2	32.8	29.1	51.5	8.92	39.6	1,676	15.6	791	606
652	2	32.3	28.5	50.6	8.82	39.8	1,645	15.6	787	619
653	2	33.2	29.2	50.7	8.92	39.6	1,684	15.6	783	607
654	2	30.7	27.7	49.3	8.55	40.4	1,598	15.3	781	618
655	2	32.9	29.2	53.4	9.04	39.4	1,682	15.9	817	616
656	2	33.9	29.9	53.1	9.13	39.2	1,724	15.8	821	602
657	2	32.3	28.7	49.7	8.74	40.0	1,658	15.4	790	595
658	2	32.1	28.7	50.8	8.69	40.1	1,654	15.2	812	604
659	2	31.9	28.3	50.4	8.83	39.8	1,632	15.6	815	609
660	2	31.8	28.5	50.0	8.74	40.0	1,644	15.6	783	607
661	2	32.0	28.7	49.3	8.71	40.1	1,655	15.5	821	633
662	2	31.5	28.2	50.0	8.74	40.0	1,624	15.5	793	603
663	2	31.7	28.5	49.4	8.68	40.1	1,642	15.6	779	572
664	2	31.3	28.1	48.8	8.52	40.5	1,619	15.2	814	564
665	2	32.5	29.2	52.0	8.91	39.6	1,686	15.6	816	590
666	2	31.9	29.1	49.8	9.00	39.4	1,679	16.1	825	586
667	2	28.4	25.8	34.5	7.71	42.5	1,490	14.2	683	645
	Average	31.8	28.5	51.2	8.78	39.9	1,644	15.5	797	595

Total number of blows analyzed: 71

BL#	Sensors
1-568	F2: [H895] 91.3 (1.00); F3: [M095] 151.8 (1.00); A1: [K5182] 345.0 (1.00); A4: [K3260] 357.0 (1.00)
569-667	F2: [H895] 91.3 (1.00); F3: [V884] 91.9 (1.00); A1: [K5182] 345.0 (1.00); A4: [K3260] 357.0 (1.00)

Time Summary

Drive 13 minutes 34 seconds 11:10 PM - 11:23 PM (12/22/2021) BN 1 - 568
Stop 4 minutes 49 seconds 11:23 PM - 11:28 PM
Drive 2 minutes 27 seconds 11:28 PM - 11:30 PM BN 569 - 667

Total time [00:20:52] = (Driving [00:16:02] + Stop [00:04:49])

Case Method & iCAP® Results

Flatiron-Lane JV, 25ENB - 25E-2E PP30"x0.625", APE D50-52
OP: RMDT Date: 22-December-2021

AR: 57.68 in² SP: 0.492 k/ft³
LE: 55.00 ft EM: 30,000 ksi
WS: 16,807.9 f/s JC: 0.90

VMX: Maximum Velocity
CSX: Compression Stress Maximum
CSI: Comp Stress Max-Individual Sens
STK: Hammer Stroke
BPM: Blows/Minute
FMX: Maximum Force
EMX: Maximum Energy
RX7: Maximum Case Method Capacity (JC=0.7)
RUC: Total capacity from iCAP

BL#	BLC	VMX	CSX	CSI	STK	BPM	FMX	EMX	RX7	RUC
	bl/in	f/s	ksi	ksi	ft	bpm	kips	k-ft	kips	kips
514	3	17.0	31.4	37.5	8.63	40.3	1,809	54.7	932	817
515	3	16.7	31.2	36.7	8.59	40.3	1,799	54.1	933	822
516	3	17.1	32.9	39.4	8.99	39.5	1,900	58.2	949	806
517	3	16.8	32.7	39.1	8.85	39.8	1,885	55.9	935	806
518	3	16.8	31.3	37.4	8.76	40.0	1,804	54.6	934	806
519	3	16.9	32.6	38.6	8.89	39.7	1,878	56.8	940	825
520	3	17.0	32.3	38.6	8.86	39.7	1,861	56.7	931	817
521	3	17.2	31.5	37.4	8.85	39.8	1,817	56.6	922	806
522	3	16.8	32.1	38.3	8.75	40.0	1,851	55.5	976	816
523	3	17.1	32.3	38.7	8.90	39.7	1,865	57.1	994	826
524	3	17.5	32.4	38.1	9.07	39.3	1,872	57.9	957	820
525	3	16.4	31.4	37.8	8.65	40.2	1,813	53.7	963	856
526	3	17.2	32.4	38.5	9.01	39.4	1,870	57.7	997	836
527	3	16.4	32.4	38.8	8.88	39.7	1,868	56.0	971	859
528	3	17.1	31.5	37.9	8.91	39.6	1,819	58.0	978	792
529	3	17.1	31.8	38.3	8.97	39.5	1,837	56.5	1,003	830
530	3	16.1	30.9	37.3	8.44	40.7	1,784	52.8	978	803
531	3	16.7	31.7	37.7	8.75	40.0	1,830	56.5	929	782
532	3	17.2	32.9	39.5	9.12	39.2	1,898	58.5	992	806
533	3	16.9	31.6	37.8	8.84	39.8	1,823	56.7	956	794
534	3	16.5	32.2	38.2	8.82	39.9	1,858	55.8	936	787
535	3	16.6	31.9	37.9	8.79	39.9	1,838	55.9	972	792
536	3	17.1	32.5	38.3	9.03	39.4	1,873	57.9	999	811
537	3	16.5	31.1	37.1	8.65	40.2	1,795	55.0	967	809
538	3	16.7	32.4	38.7	8.96	39.6	1,869	58.0	934	792
539	3	16.7	31.8	38.0	8.79	39.9	1,837	57.0	983	791
540	3	17.2	32.4	38.8	9.15	39.1	1,868	58.5	1,002	777
541	3	16.0	30.1	35.8	8.34	40.9	1,733	44.8	847	717
542	3	0.2	6.0	12.0	0.00	2.9	347	9.1	240	267
543	3	0.3	1.6	3.1	0.00	19.7	91	0.9	70	267
544	3	0.4	9.0	18.0	0.00	4.0	521	15.9	334	267
545	3	0.2	1.6	3.2	0.00	13.5	91	1.0	64	267
546	3	0.2	4.8	9.6	0.00	5.6	278	5.7	126	149
547	3	9.4	19.7	26.9	0.00	1.9	1,134	26.1	760	727
548	3	16.4	30.8	37.1	9.92	37.6	1,778	54.5	926	846
549	3	16.8	33.7	38.4	9.98	37.5	1,944	60.3	1,053	910
550	3	16.4	31.6	39.4	9.08	39.3	1,820	57.0	924	843
551	3	16.6	31.1	36.2	8.83	39.8	1,793	56.3	892	828
552	3	15.9	29.4	33.1	8.56	40.4	1,695	53.1	912	842
553	3	16.7	31.0	38.6	8.91	39.6	1,787	56.2	960	880
554	3	16.1	30.5	36.3	8.73	40.0	1,758	54.0	1,062	897
555	3	15.6	30.6	33.3	8.83	39.8	1,762	54.2	938	885
556	3	16.5	30.9	37.1	8.74	40.0	1,782	56.7	935	896
557	3	16.7	30.9	36.1	8.75	40.0	1,783	56.9	894	890
558	3	16.6	31.4	35.4	9.01	39.4	1,809	57.6	881	910

Case Method & iCAP® Results

Flatiron-Lane JV, 25ENB - 25E-2E PP30"x0.625", APE D50-52
OP: RMDT Date: 22-December-2021

BL#	BLC	VMX	CSX	CSI	STK	BPM	FMX	EMX	RX7	RUC
	bl/in	f/s	ksi	ksi	ft	bpm	kips	k-ft	kips	kips
559	3	16.7	31.9	38.2	8.95	39.6	1,837	57.6	901	907
560	3	16.9	31.5	38.4	8.91	39.6	1,817	58.8	942	853
561	3	16.9	31.0	35.0	9.04	39.4	1,789	57.6	912	833
562	3	17.3	32.0	38.1	9.15	39.2	1,848	58.8	985	849
563	3	16.5	31.5	38.1	8.72	40.1	1,816	56.2	940	864
564	3	16.9	31.0	36.3	8.84	39.8	1,789	56.8	956	838
565	3	17.1	31.9	39.0	8.92	39.6	1,837	58.1	927	816
566	3	16.6	31.2	36.5	8.71	40.1	1,799	55.9	906	816
567	3	16.8	31.8	38.0	8.85	39.8	1,833	57.3	926	824
568	3	16.7	31.7	38.3	8.84	39.8	1,831	56.8	906	788
569	3	16.0	30.9	37.0	8.55	40.5	1,783	53.7	913	794
570	3	15.5	30.1	35.8	8.27	41.1	1,735	52.4	863	794
571	3	16.6	31.3	37.7	8.72	40.1	1,805	55.6	920	808
572	3	16.7	31.1	36.6	8.75	40.0	1,793	57.0	902	796
573	3	17.6	31.8	38.4	9.04	39.4	1,831	59.1	879	798
574	3	17.1	32.2	38.6	9.07	39.3	1,858	58.4	871	805
575	3	16.5	30.6	36.9	8.50	40.6	1,767	53.7	898	773
576	3	16.8	30.3	36.2	8.52	40.5	1,749	54.5	924	782
577	3	17.1	31.0	36.8	8.80	39.9	1,790	57.5	873	770
578	3	17.2	31.0	37.2	8.86	39.8	1,790	57.3	816	758
579	2	15.9	30.8	37.0	8.50	40.6	1,776	54.4	864	754
580	2	17.0	30.6	36.8	8.68	40.2	1,762	56.4	822	766
581	2	17.1	31.7	38.2	8.92	39.6	1,827	57.9	860	772
582	2	16.9	31.1	37.7	8.72	40.1	1,792	56.0	816	777
583	2	16.6	30.3	36.6	8.47	40.6	1,749	54.8	830	762
584	2	16.6	31.5	37.5	8.80	39.9	1,816	57.6	839	760
585	2	16.8	31.6	37.4	8.91	39.6	1,825	57.7	844	758
586	2	16.8	31.2	37.8	8.70	40.1	1,800	55.4	856	771
587	2	17.2	31.3	37.5	8.82	39.9	1,804	57.1	830	749
588	2	15.9	30.9	37.1	8.49	40.6	1,783	54.0	869	750
589	2	17.1	31.2	37.8	8.80	39.9	1,799	57.0	817	720
590	2	16.5	30.8	37.2	8.57	40.4	1,778	55.0	851	733
591	2	17.3	31.8	38.5	8.95	39.6	1,834	57.9	845	726
592	2	16.8	30.8	36.7	8.65	40.2	1,778	54.1	828	720
593	2	16.1	29.7	36.2	8.27	41.1	1,715	52.1	857	761
594	2	17.3	31.5	37.9	8.92	39.6	1,818	58.4	817	764
595	2	17.0	32.2	38.5	9.08	39.3	1,856	58.8	945	754
596	2	16.0	29.9	36.4	8.26	41.1	1,727	51.5	841	777
597	2	15.9	30.7	37.1	8.49	40.6	1,770	53.9	863	759
598	2	16.7	31.3	37.5	8.83	39.8	1,806	57.8	841	748
599	2	17.1	31.2	38.0	8.87	39.7	1,798	57.3	799	721
600	2	16.6	30.5	36.2	8.62	40.3	1,759	55.0	822	767
601	2	16.4	31.2	37.7	8.67	40.2	1,800	55.3	800	743
602	2	15.8	30.0	36.0	8.30	41.0	1,731	52.9	839	748
603	2	16.9	31.6	38.4	8.86	39.8	1,821	56.8	806	764
604	2	16.2	31.1	37.6	8.69	40.1	1,796	55.3	830	724
605	2	16.7	30.3	36.5	8.52	40.5	1,748	55.2	895	738
606	2	16.6	31.9	38.3	8.94	39.6	1,838	57.0	868	734
607	2	15.6	29.4	36.3	8.03	41.7	1,697	42.6	771	758
	Average	15.7	29.8	35.8	8.79	37.9	1,719	53.0	865	768

Total number of blows analyzed: 94

BL# Sensors

1-607 F2: [H895] 91.3 (1.00); F3: [M095] 151.8 (1.00); A1: [K5182] 345.0 (1.00); A4: off

Time Summary

Drive 15 minutes 49 seconds 10:24 PM - 10:40 PM BN 1 - 607